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THE APPLICATION OF THE FUNDAMENTAL KNOWLEDGE OF PORTLAND CEMENT TO ITS MANUFACTURE AND USE.*

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Too frequently the development of Portland cement is considered to have been solely a matter of plant routine. The fact that hydraulic limes, from which Portland cement was developed and which contained those constituents that it does, were first produced as a result of investigation is generally lost sight of. However the original producers of hydraulic cements brought forward their under-burned cement as a result of research, which showed them that lime must be burned with silicious or clayey material in order to give a true hydraulic cement.

The credit for the first original research belongs to Smeaton, who wished "to have a cement, the most perfect that was possible, to resist the extreme violence of the sea" in order to build the Eddystone Lighthouse about 1756. He therefore "resolved to take every opportunity in the evenings and intervals of my attendance on the work-yard, mould-room, etc., to go through a

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complete set of experiments on cement, so far as it concerned the subject I had in mind . . . . Having now found a species of materials, and a method of compounding them very competent to our purpose . . . . I was very desirous to get some light into some of the sensible qualities, that might probably occasion the difference, or at least become a mark of distinction. I therefore applied to my friend Mr. Cookworthy, whom I had found at all times ready to afford assistance . . . . He taught me how to analyze limestone." He then goes on to show how he made his analyses and found that "the most pure limestone was not the best for making mortar, especially for building in water . . . . even the Dorking lime, much esteemed for these uses at London, and in the country round about, is plainly nothing but a species of chalk, impregnated with clay, of which it makes one full seventeenth part of the original weight." We can add that in this country, the Portland cement industry had its inception in a region (the Lehigh Valley District) where limestone "impregnated with clay" occurs in great abundance.

The product made by Smeaton was not that now known as Portland cement, but what is known as hydraulic lime. Moreover the former name did not appear until about 1824, when Joseph Aspdin, a bricklayer of Leeds, took out a patent for making a cement from limestone and clay which was called Portland cement because of the resemblance of the set product to the stone quarried at Portland, England. Between this period and that of Smeaton, several cements had been produced, all as a result of investigation which showed the necessity of the presence of impurities in the limestone. The most notable of these investigators was L. J. Vicat, whose work entitles him to be "justly considered as the creator of the industry," according to such a recognized authority as Henry Le Chatelier.

However, none of these actually produced commercially what we now consider as Portland cement. The greater part of their product consisted of a soft burned material which corresponded to what we now know as Roman, Natural or Rosendale cement or hydraulic lime. If perchance some was "over-burned" so that a clinker was unintentionally produced, it was generally discarded and only the soft burned product went into use. The composition also had not developed into that used to-day, a much lower limed raw mixture being in use. Gradually the value of the hard

burned product was recognized, and with its recognition increased the desire to produce it, until about 1875 (in this country and possibly twenty years earlier abroad) we find Portland cement as we now have it—a commercial product.

From Smeaton to Vicat the investigative work was actively pursued in Sweden by Bergmann, in France by de Morveau and Collet-Descotels, and in Switzerland by Saussure. The first of the above proposed a theory which remained generally accepted until Vicat's work—a period of almost fifty years. This theory of Bergmann is of interest particularly as showing the methods employed in the research and to what erroneous conclusions they lead. Having found by chemical analysis alone, that certain hydraulic limes of Lena contained considerable amounts of manganese, he attributed the hydraulic properties of the material to this constituent. His illustrious reputation caused this theory to be generally accepted, and notwithstanding that de Morveau could find manganese in only one hydraulic lime of France, he refrained from contradicting Bergmann. Saussure in Switzerland found the same condition but again refrained from contradicting him, though he did maintain that clay could replace manganese, but would be inferior. The value of the chemical analyses so erroneously interpreted at that time remains to-day entirely too highly esteemed, and it is with difficulty that its proper place is recognized both in investigative and commercial usage at this late date.

Vicat's work stands out prominently in every respect. It was not undertaken to develop a product, as had been so much of the previous work, but was almost solely for the purpose of determining what a material was and what in the material caused it to react as it did with water. While he busied himself almost entirely with hydraulic limes, his method of working and reasoning was such as to cause it to be followed for years. His intense interest in these limes, especially when mixed with puzzolana, led him to materially underestimate the value of the Roman cements —the nearest approach to Portland cements at that time.

Following Vicat we have a number of investigations being carried on in France and Germany. The work in England was almost entirely dropped, but plant development rapidly pursued. Germany had taken up the investigation of hydraulic limes and Roman cements actively, the first investigator, John, being contemporaneous with Vicat. He was followed by Fuchs, Sefstroms,

Pettenkofer, Winkler, Feichtenger, Zulkowsky, Heldt, and Michaelis. Some of these produced in their studies Portland cement such as we have now, though the majority confined their attention to low burned products of either the high lime (hydraulic cement) or the low burned (Roman cement) type. One observation of Sefstroms is of particular interest. In his noting about 1827 the dusting of compositions corresponding to the formula $2CaO\ SiO_2$ we have the first noting of what was but a few years ago shown by the American investigators of the Geophysical Laboratory to be the inversion of the beta form to the gamma form of this compound. In France the investigations of Vicat were continued by Berthier, Rivot, Fraemy, Landrein, and Merceron.[1]

The advances either in Germany or France are not very striking when compared with that made by Vicat. Various formulæ were assigned to the different constituents, as a result of chemical analysis of either existing cements or of the set product, or of the products resulting from leaching the cements by either water or other solutions. The value of the constituents thought to be present, as hydraulic or cementing products, was hazarded as a result of these analyses, but there was a lack of general acceptance of these theories due to an appreciation of the lack of proper approach to the problem.

Le Chatelier by his work published in 1887 brought prominently into usage the microscope first used in cement investigation by Winkler. By using the microscope to examine the products produced by burning definite mixtures, by means of chemical analyses of these and of commercial products, he announced the composition of Portland cement to be a tricalcium silicate, tricalcium aluminate, "calcium ferrate" and "multiple silicates." These conclusions remained partly confirmed but never adequately disproven by such eminent foreign investigators as Michaelis, Oddo, Tornebohn, Rebuffet, Rohland, or our own Newberry and

[1] It is not thought advisable in the space of a short paper to give the many references where the work of the above investigators can be found. These, together with a valuation of the work of each, may be found in the four following publications: "Experimental Researches on the Constituents of Hydraulic Mortars," Le Chatelier, translated by J. L. Mack, published by McGraw-Hill; "Cement," Betram Blount, published by Longmans-Green & Co., London; "Der Portland Zement," Schmidt, published by Konrad Wittwer, Stuttgart; "Die Chemie der hydraulischen Bendemittel," Kuhl and Knothe, published by S. Hirzel, Leipzig.

Richardson, until the eminent work of the investigators, especially Rankin, of the Geophysical Laboratory of the Carnegie Institution. It should be stated as a special credit to Le Chatelier, that while even the latter at first did not confirm the existence of the tricalcium silicate yet the final work of Rankin gave it the prominent place assigned to it by Le Chatelier. The very excellent work of Newberry must also be given a prominent place on account of the wide acceptance by the cement manufacturers of the ratio suggested by him as a means of controlling the composition.

The publications of the Geophysical Laboratory, in connection with their investigation of the system lime-silica-alumina, have given us a true insight into the constitution of Portland cement. Applying the phase rule by means of the best experimental methods of physical chemical attack, coupled with an extensive use of the petrographic microscope, they have shown that well-burned clinker contains tricalcium silicate, dicalcium silicate, tricalcium aluminate, and a certain amount of slag or glass high in oxide of iron.[2]

It is difficult to appreciate the enormous amount of experimental work done in this investigation, but some slight realization of it may be gained from the fact that "some 7000 heat treatments and subsequent optical examinations of the product" were made. The very stupendousness of the work precludes its duplication within any reasonable period, but at the same time the correctness of the conclusions has been checked many times in the course of work which included not only those compositions which are included in Portland cement but also all those of the entire ternary system. Here and abroad generally the results have been accepted as conclusive. In Germany the prejudice against accepting the existence of tricalcium silicate so strongly insisted upon by Le Chatelier, continues, and several poorly designed and poorly carried out investigations have been made to prove that this is a ternary compound containing a small amount of alumina.

In order to apply on a large scale certain of the generalizations made in some of the first papers of the Geophysical Laboratory the Bureau of Standards erected at its Pittsburgh branch an experimental cement plant during 1911. This was equipped with complete grinding apparatus and a 2′ x 20′ rotary natural gas kiln.

[2] "Portland Cement," Rankin, JOURNAL OF THE FRANKLIN INSTITUTE, vol. 181, 747.

A series of burns was outlined in which a wide variation in the composition was maintained. After burning, a complete chemical and petrographic analysis was made. The clinker was then ground and from the resulting cement the different small physical test pieces were made, as well as concrete test pieces in the form of 6 x 12 cylinders, which were broken at various periods. Such an investigation would serve to show not only how the various constituents would affect the strength, but also how the strength would be affected by variations in the amount of the constituents. Another series on a smaller scale was carried out wherein pure alumina, silica and lime were used. These latter, on account of preventing contamination from kiln linings, were not made in the rotary kiln. Also in order to secure the silicates separately a higher temperature was desired than attainable in a rotary kiln. This series would serve to show the relative setting and hardening properties of constituents uninfluenced by the presence of a second or influenced by a definite amount of a second added by mechanical mixing after separate preparation.

These investigations, presented to the public partly in Bureau of Standards' Technologic Papers Nos. 43 and 78, have not only borne out the conclusions of the Geophysical Laboratory, but have applied them to elucidating the chemistry of hardening.

The much discussed tricalcium silicate was prepared containing little more than traces of alumina. It was found to have all the setting and hardening properties of ordinary Portland cement. The dicalcium silicate of the same degree of purity was found to harden so slowly that it had no commercial value. However, if allowed to remain in contact with water for a period of from two to three weeks it gradually hardened until at the end of three or four months it had as great a strength as the tricalcium silicate or Portland cement. The tricalcium aluminate when pure hydrated almost instantly with a marked evolution of heat and never secured a true set or hardening.

These conclusions naturally give rise to certain questions. If the tricalcium silicate has all the properties of Portland cement, why not manufacture it alone in the absence of the very slow setting dicalcium silicate or the non-hardening tricalcium aluminate? Has either the dicalcium silicate or tricalcium aluminate any essential functions either in the process of manufacture or usage? If the tricalcium aluminate alone reacts almost instantly with water

and does not set, how are these properties masked in the finished cement?

These questions require a study particularly of the work of the Geophysical Laboratory. The latter has shown that the tricalcium silicate starts to form from the oxides at 1400° C. through the intermediate formation of the dicalcium silicate. This combines at higher temperatures, or with a longer heating with more lime, to form the tricalcium silicate. This disintegrates at about 1920° to the dicalcium compound and free lime. But the most striking feature in regard to the tricalcium silicate is the fact that "it is found as a primary phase only within the ternary system." Hence the possibility of obtaining this pure at commercially obtainable temperatures in quantities at a cost to compete with the price of Portland cement is out of the question. The work of this Bureau does not show that such a pure product would have cementing qualities which would justify much greater cost than Portland cement. The possibility of using a cheaper material than alumina to form a ternary system is not likely, as by the use of clay, especially widely distributed and very cheap, two of the three oxides desired are readily obtained. The Bureau in its work used either the oxide of boron or chromium, neither of which is sufficiently cheap to compete with alumina. In this work not one but six successive burnings were required to produce the compound containing less than 2 per cent. of free lime. Why it would not be possible to produce it on a commercial scale under present methods is hence quite evident.

The dicalcium silicate forms much more readily than the tricalcium compound, especially in the presence of a third oxide, as alumina, and is not decomposable at its melting point. Mixtures of silica and lime such that this compound would form react rapidly and at commercially obtainable temperatures. The presence of alumina in small amounts decreases the temperature required to bring about the formation of the compound. This compound after a month or more of its slower hydration has a strength approximately equal to the higher lime compound, but its water of hydration is only about one-third the latter. It is the more stable product of the two silicates in respect to water and hence would be the more desirable to resist weathering so far as solubility is concerned, if it were not for the fact that after setting it has a very sandy structure and is not free of voids. It hence

contains cavities in which water may freeze or salts crystallize, and in this respect does not offer a good medium for weathering. The tricalcium aluminate by its rapid hydration assists in breaking up the granules of finely ground clinker and also in increasing to a slight degree the hydrating of the silicates. Any free lime existing in the clinker or that formed by the hydrating of the silicates, in the presence of gypsum added for regulating the set, very markedly reduced the reaction of the aluminate with water and actually gives this compound some cementing qualities. In the previous paragraph attention was called to the slow rate of hydration of the dicalcium silicate. The slow hydration noted and the open sandy appearance both require the presence of another material which will hydrate rapidly and to a denser mass. These two properties are furnished in a striking manner by the tricalcium silicate. It was found that mechanical mixtures of these two silicates in equal amounts produced a cement which had the desired density of Portland cement after hardening, and at late periods a very comparable strength. Later examinations of commercial clinker showed that in these mixtures the amount of high limed compound was low and that with mixtures of the correct proportion a product equal to Portland cement would doubtlessly have been obtained.

Before leaving the subject of pure compounds it would be desirable to call attention to certain of their properties which have been noted by different investigators, but in certain cases not fully explained. The presence of uncombined lime in these and in Portland cement has been a matter of much discussion. Thus, in the tricalcium silicate used in part of this investigation as much as 2 per cent. of free lime was noted, but the silicate was sound according to the usual test—because the test piece had attained a strength before test in excess of the disruptive force developed by the hydrating of the lime during the test. The dicalcium silicate hardens so slowly that it is likely that it would have to be aged a month before it would have sufficient strength to be sound in the presence of the same amount of lime. The dusting of dicalcium silicate and of low burned or too high silica Portland cement is a commonly noted phenomenon. This is due to the inversion of the beta to the gamma form of the dicalcium silicate with an increase in volume of about 10 per cent. Whether this inversion may be delayed to a late period, as for instance after the cement has gone

into a concrete, with consequent destruction of the concrete, has been discussed repeatedly. The Bureau has made a number of cements in which the clinker dusted slowly (it is surprising how much many clinkers will dust in the course of three or four years). But it has not been able to note any destruction of set cement in any form in specimens made of these cements. Disintegrated concretes made of commercial cements have been examined for the same purpose, and none of the gamma form noted. A number of investigators have questioned the possibility of hydration of the dicalcium compound. This has been due, however, to their not observing the phenomenon of its hydration over a sufficiently extended period. Test pieces made of it cannot be handled at the end of a week without breaking. At the end of a year they will have attained strength approximately equal to that of Portland cement, but will have acquired only about 5 per cent. water of hydration. Crystals of hydrated lime are plentiful in the specimens, showing the breaking up of the compound to a silicate of lower lime content. The tricalcium silicate will have acquired at the end of a year more than twice the water of hydration of the dicalcium compound. The former compound also gives off lime during its hydration. Many investigators have noted that the tricalcium aluminate sets and hardens. However this is another compound which decomposes at the melting point, giving off lime. If the two oxides, in the proportions to form $3CaO\ Al_2O_3$, are heated to the point of vitrification, $5CaO\ 3Al_2O_3$ and CaO result. The true tricalcium aluminate free of lime can be obtained only by heating the oxides for a long period at a temperature of about 100° below that required for vitrification (about 1450°, dissociates at 1535°). This mixture of $5CaO\ 3Al_2O_3$ and CaO sets and hardens rapidly and could be used as a very quick setting cement. It is this mixture which has been the subject of investigation, as it and not the true tricalcium compound has been obtained in by far the majority of cases. Chemical analyses will not determine whether the compond $3CaO\ Al_2O_3$ is formed. The microscope is essential to determine the free lime.

The work which the Bureau carried out in its rotary kiln has been of particular value in showing the amounts of the several constituents that may be obtained in general manufacturing practice, and how these affect the product as a cementing agent. In this work the composition of approximately 50 cements (each

made after burning a half ton of raw material) was varied so that the tricalcium silicate content ranged from a trace to approximately 51 per cent. The dicalcium silicate varied from 12 to 74 per cent., and the tricalcium aluminate from 14 to 33 per cent. These figures were obtained by petrographic examination of thin sections of clinker. The data have been studied in a great many ways—by the plotting of strength at various periods against the ratios suggested by Le Chatelier, Michaelis, Newberry and others, as obtained from the chemical analyses; by plotting the strength against the amount of the constituents as obtained by petrographic analyses, and by plotting the strength against molecular formula, calculated both

TABLE I.

Showing the effect of the di- and tricalcium silicates upon the strength, in pounds per sq. inch, at different ages, of cements in a 1:1.5:4.5 gravel concrete. Arranged in groups depending upon the SiO_2-Al_2O_3 ratio.

Average $\frac{SiO_2}{Al_2O_3}$	1.25	1.75	2.25	2.75	3.25	3.75	4.25	4.75
3 CaO SiO_2	36.3	22.0	30.2	26.1	16.2	31.4	21.1	7.6
3 CaO SiO_2 plus 2 CaO SiO_2	54.8	57.5	65.1	43.0	71.5	72.6	68.9	67.0
Strength at 4 weeks	1660	1205	1655	1315	960	1560	1560	570
Strength at 1.5 yrs.	2375	2265	2700	3110	2670	3215	3240	2705
Strength at 5 years	2650	3020	2960	3290	3170	3470	3610	3305

from the chemical and petrographic analyses. The majority of these show but little of interest, while others bring out striking facts. But the most striking feature of all is that composition or constitution are meaningless so far as predicting the quality of a cement unless the period of hardening is considered. This can be realized from what has been stated before in regard to the speed of hardening of the several compounds. Table I, presenting certain of the data, will show this fact, and at the same time illustrate one of the methods of presenting the data in such a tabular form as will show a comparison of one of the common ratios with changes in constitution and with strengths produced in concrete at certain ages.

The data in Table I have been arranged by placing each of about 50 cements, all made at the Bureau, in one of several

groups depending upon whether the silica-alumina ratio lay between 1.00 and 1.50; 1.50 and 2.00; 2.00 and 2.50, etc. In the table the first group above is given in the second column under the ratio 1.25, the second under the ratio 1.75, etc. These ratios were obtained from the analyses of the clinker by reducing these by calculation to the 5 compounds—silica, alumina, iron oxide, lime and magnesia as equaling 100 per cent. The amounts of the two silicates were obtained from petrographic analyses of thin sections of the same clinker. In the table the amount of either constituent is the average of all the cements in the group. The strength was the average of the 6 x 12 concrete cylinders for all the cements in the group.

The difficulty of deriving any conclusions from such a tabula-

$\frac{SiO_2}{Al_2O_3}$	$\frac{CaO}{SiO_2+Al_2O_3}$	CaO equivalent to $2.8SiO_2+1.6Al_2O_3$	CaO by analysis	$3CaO.SiO_2$	$2CaO.SiO_2$	Strength of 1:1.5:4.5 concrete tested at		
						4 weeks	1.5 yr.	5 yrs.
2.29	2.17	65.8	64.1	61.8	16.8	2380	3845	4510
2.71	2.26	64.9	65.1	51.5	18.0	2480	4260	4750
3.35	2.33	65.0	65.9	49.8	22.0	2700	4530	5150
1.67	2.16	64.5	64.5	29.5	25.0	1925	3130	4180

tion is immediately apparent, but the reason for the difficulty is not so evident. It is, however, due to the fact that in any group we have the tricalcium silicate ranging from a very small amount to a very large one—as for instance in the group with a ratio of 3.25 it ranges from a trace to 49.8 per cent. In other words a ratio depending upon the composition may classify as similar, cements which differ widely in their constitution. The same applies to all other ratios that have been proposed, whether they are based upon either a percentage or a molecular basis. This is further illustrated in the following tabulation of data secured from the examination of but four cements and the concrete made from them.

It is clearly evident from the above that the silica-aluminum ratio in these four cases again fails as a criterion of the value of a cement; that the lime-silica plus alumina ratio as well as the Newberry formula, shown at the top of the third column, does not predict the amounts of the constituents although for late periods

it is a fair index of the strength. The failure of the lime-silica plus alumina ratio can be readily appreciated from the wide variation in the relative amounts of silica or alumina that is possible and yet have their sum constant. The use of molecular quantities instead of percentages does not materially affect the significance of this ratio derived from several cements, although it does change the numerical value.

The Newberry formula, on account of its very wide application in plant control, was studied more closely by grouping 23 cements which did not deviate too much from normal commercial composition into three groups. In the first group the average lime content, as found by analysis, was in excess of that calculated by the Newberry formula; in the second it had approximately

CaO equivalent to $2.8SiO_2+1.6Al_2O_3$	CaO by analysis	$3CaOSiO_2$			$2CaO.SiO_2$	Strength of 1:1.5:4.5 concrete tested at		
		Average	Maximum	Minimum		4 weeks	1.5 yr.	5 yrs.
59.8	65.6	40.8	43.1	37.2	14.3	1865	2565	3000
65.3	64.9	38.9	51.8	23.4	26.1	2030	3435	3735
70.8	62.6	25.5	44.7	14.3	38.3	1400	2775	3210

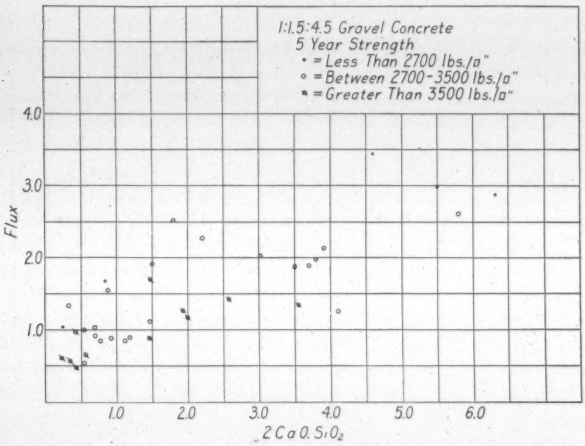
the same value, and in the third the lime content was considerably below that derived from the formula. The above tabulation shows the results of this grouping, together with the average strength of the cements in the group and data concerning the constituents.

Again the formula apparently is of no service in predicting the constitution, but the failure is due either to differences in degree of burning or in composition. Thus the compositions of the cements showing maximum and minimum tricalcium silicate in the second group are very similar, but the one with minimum tricalcium silicate was decidedly underburned and unsound—although it had a strength of 3765 pounds per square inch in the concrete at the end of five years. In the third group the cement with the minimum tricalcium silicate was one with a high alumina content and low lime and silica, whereas the one with the maximum content was a low alumina but high lime and silica content. However, an analysis of the data from all the cements shows that this formula

is the superior of any of the ratios ever suggested. But even it cannot be used to make deductions as to the quality of a cement from the results of chemical analyses, particularly on account of the latter not showing the degree of burning.

How the petrographic analyses will predict the cementing qualities can be inferred from the above tables and discussions. It can also be grasped by a study of Figs. 1 and 2. In preparing these, the clinker has been considered as being composed of but three

FIG. 1.



constituents—the dicalcium and tricalcium silicates and the "flux." These, as determined by the petrographic microscope, embrace all the constituents and hence equal 100 per cent. In the "flux" is embraced the tricalcium aluminate, the possible "ferrites" and the "glass" more or less colored by the iron oxide. By simply dividing in each analysis the percentage of each constituent by the per cent. of tricalcium silicate, we obtain a formula for each cement of the type—

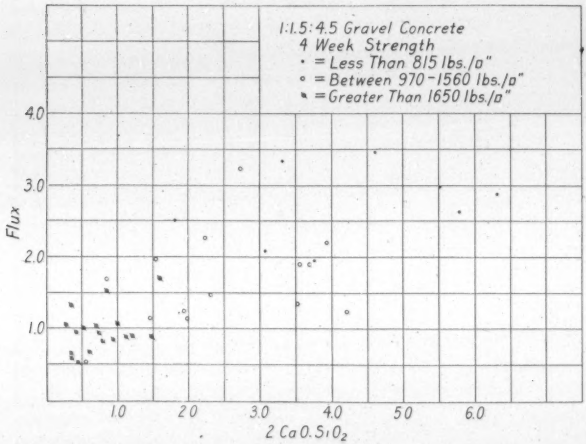
$$3CaO.SiO_2 : x2CaO.SiO_2 : y \text{ "Flux."}$$

In all cases the first constituent being unity we may plot the location of the other two on ordinary rectangular coördinate paper.

These locations can then be indicated by such marks as will indicate as to which of several groups it belongs in so far as its strength at any age is concerned. This procedure has been followed in preparing Figs. 1 and 2.

From these it will be noted, as previously stated, that the effect of the tricalcium silicate at the four-week period is very marked in producing high early strengths. This is shown by the fact that those cements low in dicalcium silicate and "flux" fall in the

FIG. 2.



lower left hand corner of the figure, while the locations of the others are stretched out across to the upper right hand corner. The location of each cement is indicated by one of three marks depending upon the strength of the cement as indicated by the concrete specimens. In the case of the four-week specimens, the marks indicate strengths ranging from 345 pounds per square inch to 2700 pounds, while at five years the strengths range from 2110 pounds to 5150 pounds. As at the former period the maximum value is about six times the minimum, while at the latter period the maximum is but two and a half times the minimum, the effect of the dicalcium silicate in conferring strength with age is readily seen.

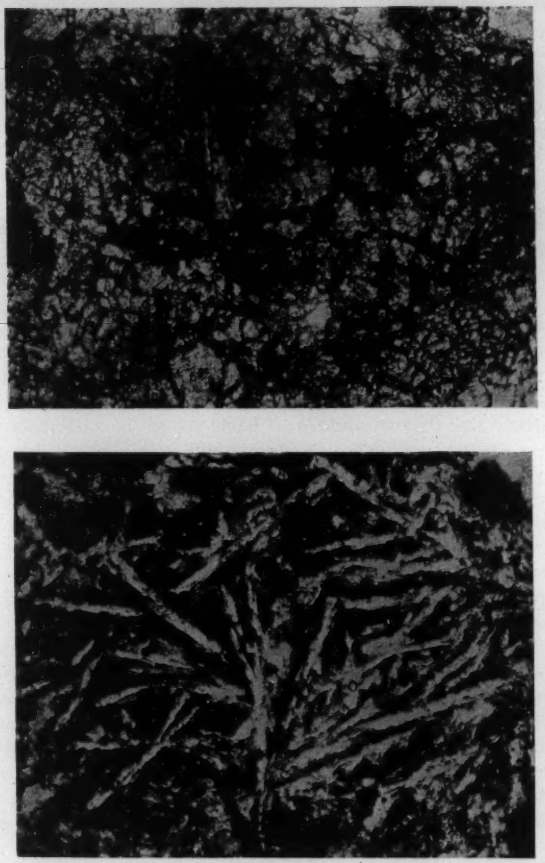
These figures also present the opportunity of deriving a formula for cement of best general strength qualities. They show that when the dicalcium silicate exceeds 1.5 molecular ratios the strength at four weeks will be low, though for best results this should not exceed 1.0; but if late strengths are considered then it may reach 2.0 and be of good quality. The flux should not exceed 1.0 in any case. Hence the formula would appear for early strength as

$$3CaO.\ SiO_2 : 2CaO.\ SiO_2 : \text{"Flux."}$$

If the flux were pure tricalcium aluminate this formula would reduce to a percentage composition of 66.9 per cent. lime, 18 per cent. silica, and 15.1 per cent. alumina. Such a composition, however, would not be obtained from averaging the chemical analyses of the cements in question, neither would it represent the composition of commercial cements. Hence we have rather strong evidence that the "flux" contains silica as well as all the alumina and approximately all of the iron oxide. It indicates quite clearly, however, that the two silicates are likely present in equal molecular ratios. A mixture of the two silicates only in this ratio would give 30 per cent. silica and 70 per cent. lime. Hence the percentage of silica by 2.33 equals the percentage of lime, which is rather a close approximation to Newberry's ratio of 2.5. It is, however, very interesting to note that a purely scientific investigation, carried out entirely from the viewpoint of constitution, should confirm commercial Portland cement manufacturing practices in the use of present compositions.

It is evident that so far as early strength is concerned a cement of relatively high tricalcium silicate content is desired (see Figs. 3 and 4). Such a cement not only gives high early strengths but does not apparently lose strength with age. (It can be readily noted, however, that it does not have a high rate of strength increase with age.) Therefore the possibility of producing cements with a high content of this constituent is very attractive. The use of other fluxing or catalyzing agents than alumina have been suggested. The iron oxide occurring as an impurity in the clay and magnesia as an impurity in the limestone act in this capacity, but cannot be used to a greater extent than that now done commercially without adversely affecting the required properties. The former, in excess, gives a slow setting product and the latter in

FIG. 3.



Upper.—Photomicrograph of a section of clinker of normal composition, nicols of microscope crossed. Note the large, poorly defined grains and lack of crystalline structure; contrast with lower photomicrograph of a section of clinker of approximately 17 per cent. silica, and 11 per cent. alumina content, and note large crystals of tricalcium silicate. Such a cement is not quick setting and deports itself in the kiln as one of normal composition. Magnification in both cases—135 diameters.

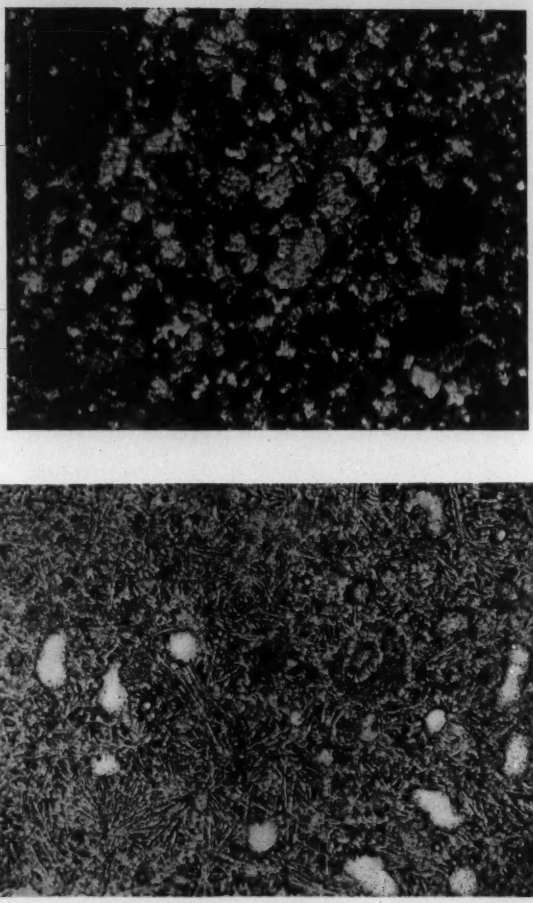
addition to slow hardening gives difficulties in manufacture through the formation of excessively large clinker which reduces kiln output.[3] The Bureau in its experimental plant made a series of burnings using calcium fluoride to replace some of the limestone and another in which boracic acid was used. The results were disappointing, as in both cases a slow setting and hardening product was obtained, although the lime content exclusive of magnesia was carried close to 70 per cent. However, under these conditions the cements were sound, although the test pieces had to be aged 48 hours before testing, as at earlier periods final set had not been acquired.

High tricalcium silicate can also be obtained by increasing the lime content and reducing the silica. This demands a higher temperature for burning, which in turn increases the cost of production if present procedure is followed. The possibility of an entire change of production procedure is attractive and of interest. It is well known that burning at a lower temperature for a longer period will produce the same result as burning at a high temperature for a shorter period. Hence the suggestion of trying kilns of the tunnel type instead of the rotary type. For use in such a kiln the raw material after grinding would be briquetted, placed upon cars and passed through the tunnel, a certain section of which would be heated to the desired temperature. The heated products of combustion could be directed to a waste heat boiler or to preheating the briquettes entering the kiln. This type of kiln, so far as fuel conservation is concerned is the most economical now in use and that it could be used to reach a temperature as high as that required for burning cement is evidenced by its usage for burning fire brick. Modern machine methods for making, molding and handling brick would reduce the apparent cost of this part of the procedure to a minimum. The economy of such a kiln is further realized by the fact that practically the entire section of the kiln is filled with the charge, while in the rotary kiln only a very small section is in use at any time.

Another suggested method is that of the use of admixed fuel in the raw material in the form of coke breeze, anthracite culm,

[3] *Technologic Paper No. 102 of the Bureau of Standards,* "The Properties of Portland Cements Having a High Magnesia Content," gives the results of a study of the effect of magnesia in cements conducted along the lines of the investigations under discussion.

FIG. 4.



Upper.—A photomicrograph of a section of clinker of normal composition, nicols crossed, magnification 90 diameters. Lower.—Of a section of high alumina cement, magnification 40 diameters. See remarks under Fig. 3.

etc. Some preliminary work at the Bureau indicates that the combustion of the fuel in such close contact with the raw material as is brought about by this procedure materially reduces the temperature and fuel required. Further confirmatory work on a large scale is contemplated and partly under way.

The oft repeated suggestion of fusing the clinker in something like a blast furnace will not be quieted until it has been actually shown to be a success or failure. This like the previous suggestion when carried out in a modified blast furnace carries with it the use of a solid fuel in contact with the raw material. Recently considerable attention has been directed to "fused cement" being produced in an electrical furnace in France. This is not, however, Portland cement (which latter must be considered silicates of high lime content with the tricalcium aluminate as a minor constituent), but is one or both of the highly aluminous lime aluminates ($CaO.Al_2O_3$ and $3CaO.5Al_2O_3$), with a low limed silicate or silico-aluminate of lime as the minor constituent. This class has been under investigation for a number of years by the Bureau, whose recent publication, Technologic Paper No. 197, gives the results. They are indeed wonderful cements, but do not require fusing for manufacturing, but on the other hand require a source of cheap alumina, which is not available in this country. Fused Portland cements of usual composition do not appear very desirable or necessary. They would require excessive cost in burning and subsequent grinding. Also it is a matter of daily practice to secure cements free of uncombined lime in the ordinary clinkering process. Harder burning, even to the point of fusion, cannot secure more or even a different combination of the compounds, unless the lime content were increased beyond that usually used. In such a case a higher temperature would be required to complete the reaction between the dicalcium silicate and the lime, the temperature needed depending entirely upon the amount of lime present in excess of that now commercially used. On the other hand it should be borne in mind that at 1900° the tricalcium silicate decomposes into the dicalcium and free lime. At that temperature the decomposition is complete, but starts considerably lower. Hence in a fused clinker of the usual composition, rapidly cooled, free lime would be present.

At the present time there is but one standard for Portland cement, no matter into what use it ultimately goes. Is this good

practice? The answer must be in the affirmative if considered from the viewpoint of our present knowledge of cement testing. The practical cement user, however, has answered the question negatively in many cases—when he uses one or more brands in preference to others for certain classes of work or at certain periods of the year. In this connection may be cited the belief that certain brands always produce a non-dusting floor, while other brands produce a dusting floor. In all cases the various brands invariably meet the requirements of the standard. The requirements of the latter do not bring out the differences which usage has found to exist. Hence for certain uses special tests will have to be devised which will determine the desirability of any brand over another for any particular case. The question arises as to what is a particular case. Should cements for massive construction be different from those for road construction, or for interior pavement or for seawater or alkali work, or for reinforced concrete? The former does not of necessity demand high tensile or compressive strength like the latter, while for the pavement strength is of relatively minor importance when compared with non-dusting. For seawater or alkali resisting work the physical properties are relatively of minor importance when compared with the need of resistance to chemical action.

High compressive strength can be secured by a high tricalcium silicate content, a silica content of about 20 per cent., a usual alumina content and hard burning of such a raw mixture ground more finely than is usual. Such a cement, however, is brittle and of low tensile strength after an early age, hence it is not desirable for road work. It commends itself for floors but requires special skill in handling or it will dust continuously. Material changes in our present tests would have to be made to show the value of any marked changes in methods or procedure of manufacture. Earlier strength tests than seven days would be required; both a tensile and compressive test would have to be considered and a test to determine the coefficient of expansion with age. If by change in composition it can be shown that a cement more resistive to salt action can be secured it may be necessary to incorporate further chemical determinations in our specifications. The possibility of determining the quality of the cement in a concrete at a late age by an accelerated test, in other words determining its cementing qualities when it has largely hydrated, is worthy of much research.

Hence aging at higher temperatures in an atmosphere of water vapor should be a subject of much further and more logical work than heretofore.

This is truly the "Cement Age," but the development of the cement is in its infancy notwithstanding that in this country, where it has secured its widest and most daring application, it is hardly more than fifty years old. But the industry while growing old has developed too broadly physically and too narrowly mentally. After the first few years of a well-balanced development the environments furnished such strenuous physical exercise in developing a market against foreign competition and keeping up with the market once developed, that a magnificent physique was developed but mentally equipped only to keep this physique of production in condition. Recently, however, cost problems and service questions (in particular) have forced the industry to consider its mental shortcomings, and it is now engaged in overcoming these by such thought of technical matters along various lines as serve to demonstrate that it will be able to discuss and settle them in due course along well-developed scientific lines.

The Application of Anode Rays to the Investigation of Isotopes. G. P. THOMSON. (*Phil. Mag.*, November, 1921.)—The author of this paper is the son of Sir J. J. Thomson. Among British physicists there is at least one other of the second generation, Lord Rayleigh. In this connection the names Bernouilli and Berthelot will suggest themselves to the reader. Perhaps there is no better illustration of the transmission of scientific ability from father to son than in the case of R. Kohlrausch whose two sons, W. and F. Kohlrausch, both won distinction and two of whose granddaughters were wedded to men of scientific attainments, W. Hallwachs in Leipzic and Professor Day in Washington.

There are four ways of getting positively charged metallic atoms in the search for isotopes by electromagnetic analysis:

1. By sending an electric discharge through a volatile compound of the metal. Aston used this method with nickel carbonyl, but it is limited in application.

2. Dempster's method of volatilizing a metal, not yet fully described.

3. Positive particles emitted by salts heated for the purpose. A very low pressure in the gas is required.

4. Anode rays given off by an anode under bombardment by gaseous ions. In this method a moderately high pressure is used.

The last method was employed in the present research. The

anode was made by packing into a quartz tube powdered graphite and a halogen salt of the metal to be examined. When the discharge passes, there is a glow on the surface of the anode and a beam comes out from the surface. A fine pencil of this beam of anode rays is separated by letting the whole fall on a tube having in it a hole only .2 mm. in diameter. The small pencil that gets through is then subjected to the simultaneous influence of magnetic and electro-static fields whereby the rectilinear ray is bent into a parabolic form from whose dimensions it is possible to calculate the atomic weight of the atoms in the ray. The form of the parabola is recorded on a photographic plate.

Lithium is found by Mr. Thomson to consist of isotopes having atomic weights of 6 and 7. The line due to the 6 constituent was "sometimes considerably stronger than would be expected from the atomic weight, 6.94." Beryllium gave no sign of having atoms of atomic weight different from 9. Calcium and strontium lay without the limit of the resolving power of the apparatus used. "It is, however, certain that one or more of the atomic weights (39, 40 and 41) were present (*i.e.*, when calcium was tried); and as all these are already known to exist as isotopes of other elements (39 and 40 potassium, and 40 argon), it is clear that calcium is an instance of a so-called isobar. No previous instance had been known except among the radio-active elements."

It is to be hoped that the word "isobar" in this sense will be replaced by some other term, since isobar already has quite a different meaning in meteorology.

G. F. S.

Selenium and Tellurium Compounds as Intensifiers of Gasolin. (*Am. Chem. Soc. News Serv.*)—Authoritative reports from the laboratories of the General Motors Company give information that by the employment of selenium oxychloride or diethyl telluride the efficiency of a given amount of gasolin can be doubled. The data have been obtained by Midgley and Boyd. The tellurium compound was the most efficient, and is especially advantageous in eliminating the "knock" which is developed when a motor is laboring on a grade. Victor Lenher states that if only one hundred of one per cent. should be used in gasolin, the amount of tellurium required in the present use of gasolin in the United States will be 1500 tons. In 1920 it was ascertained that without further plant equipment the country could reduce only a little over sixty short tons. It will be necessary to find new sources of tellurium and also of selenium if these materials are to be extensively employed. A very important point will be the sanitary problems, which apparently have not yet been considered. Selenium and tellurium compounds are mostly quite poisonous.

H. L.

GASOLINE FROM OIL SHALE.*

BY

RALPH H. McKEE.

Professor of Chemical Engineering, Columbia University, New York City.

PROBABLY the first thing that I should do is to define my terms. All of you have a general idea of what gasoline is, and yet you might have some difficulty in defining it in a way which would be altogether clear. For the present need gasoline may be defined as a hydro-carbon distillate, generally a petroleum distillate, 90 per cent. of which boils below 374° F., and all of which boils below 437° F. It has a density of less than 50° Be. To be commercial gasoline it must, in addition, have but slight color and be free from certain types of impurities.

Oil shale is a type of shale occurring in considerable quantities in various parts of this country and also in many other parts of the world. On heating this it gives a petroleum from which a motor spirit similar to ordinary gasoline can be obtained. In passing, I wish to call your attention to the fact that the word "petroleum" was used for shale oil for more than twenty years before the discovery of the first oil well.

In the belief that you will be interested in a brief preliminary discussion on the present day sources of gasoline and of its possible substitutes, I would like to discuss their manufacture.

Twenty years ago all the gasoline used was obtained as the light low boiling distillate from crude petroleum. This distillate which might be called crude gasoline was then chemically treated to give the refined gasoline. The chemical treatment consisted in stirring it with concentrated sulfuric acid to remove the coloring materials, ill-smelling compounds, certain substances commonly called unsaturated compounds, and small amounts of certain basic constituents. After this sulfuric acid wash, gasoline was washed with an alkali, generally caustic soda. Following this wash with alkali solution the gasoline was redistilled and a very fine quality of product resulted. It is quite easy to make a good quality gasoline from such a quality of petroleum as Pennsylvania petro-

* Presented at a meeting of the Section of Physics and Chemistry held Thursday, January 12, 1922.

leum, but when the Pennsylvania fields began to decrease in output and the lower quality of oils from Ohio, Canada, the Middle West and the Far West came into the market, it was found that they did not give either as large a percentage of gasoline or a product of as high a quality as had been given by the Pennsylvania oil. On the other hand, the demands for gasoline due to the growth of the automobile industry were increasing.

The effect of this change of the commercial situation was that lower grade gasolines began to come into the market. These were lower grade in that they carried some of the higher boiling kerosene fraction, some color and some of the unsaturated constituents which give a stronger odored product. Each phase of this lowering of the standard brought about distinct increases in the amount available, but even under these circumstances the demand has increased faster than the supply, and accordingly there have been attempts to use other products to supply the deficiency. These attempts have given rise to three new petroleum products, casing head gasoline, natural gas condensate and cracked gasoline, as well as substitutes quite different from petroleum products.

When a higher boiling petroleum, of the type of the low priced fuel oil or gas oil, is heated to a temperature of around 700° F., there is a decomposition of this oil with separation of carbon on the one hand and the formation of light boiling constituents of the type of gasoline and kerosene on the other hand. This process is known as the cracking of oil and the lighter of the commercial products made is known as cracked gasoline. Cracked gasoline carries up to 40 per cent. of unsaturated compounds. Formerly we considered that a gasoline carrying as much as 5 per cent. of unsaturated constituents was not desirable or available for use in an explosive engine. To-day much of the gasoline on the market is a mixture of cracked gasoline carrying 40 per cent., with straight distillate gasoline of low unsaturated content. I do not know what your local situation is here in Philadelphia, but in New York it is not uncommon to have gasoline put into your car carrying 20 per cent. unsaturated constituents. This unsaturated product means that you have a gasoline which on standing and in contact with the air becomes colored and after a time even separates a small amount of brown tar-like deposit. This red-brown sample was formerly a water-white cracked gasoline of 30 per cent. unsaturates. It also

has a more unpleasant odor than the saturated straight distilled gasoline. On the other hand, may I inquire who of you purchases gasoline as a perfume or on its looks?

I should add that the automobile of a few years ago would not run well on the present day gasoline. It is certain that the gasoline on the market is destined to grow in its content of unsaturated compounds, and we must look to the engine designer to at least keep up and even with the changes in the type of fuel available.

There are several schemes which have been used on a large scale for making cracked gasoline. Of these the one which has been used on the largest scale is that of Dr. W. M. Burton, now President of the Standard Oil Company of Indiana. This is the process now being used by various Standard Oil companies and by which they make approximately two million gallons of gasoline a day. Burton starts, as do all other cracking schemes, with a cheap petroleum residual, preferably one of the Pennsylvania or mid-continent types. The particular point in which his process is distinctive is that he heats under a pressure of about 75 pounds, and does not relieve this pressure until after the vapors have passed through the condenser. Heating of the oil is accomplished in a steel still tank by a fire placed directy beneath it. The temperature varies during the process, but averages perhaps 700° F.

Any scheme of cracking is handicapped by the deposition of coke on the bottom and sides of the still. Burton's process suffers severely from this trouble. The original patent claims that the process gives a product free from unsaturated compounds. However, the products at present made do carry a considerable percentage of unsaturated material. The method is fairly cheap to operate but suffers, as before mentioned, from heavy flinty carbon deposits, high deterioration of stills, the dangers to operators, and also because the products formed are too unsaturated to be of the highest grade.

It may interest you to know that this development of oil cracking is to be recognized to-morrow night (January 13, 1922) in New York by the bestowal on Doctor Burton of the Perkin Medal by the American Section of the Society of Chemical Industry. The Perkin Medal is given for high attainment in the industrial application of chemistry.

Other workers have attempted to get away from the troubles of the Burton process, in particular the heavy carbon separation

and unsaturated character of the product. Doctor Rittman while a graduate student at Columbia University developed a process in which the cracking is carried out in the vapor phase instead of as a liquid. His apparatus consists of externally heated vertical pipes through which the vapors are passed under pressure. The process is one in which a pressure of 300 pounds may be used. A temperature of about 700° F. is used. By reason of the reaction being in the gaseous stage instead of liquid, the amount of carbon deposited is small, the products, however, like those of Burton, are partially unsaturated.

The third process which has been carried out in commercial plants is that of McAfee. Doctor McAfee, like Doctor Rittman, is also a graduate of Columbia. McAfee avoids the use of pressure and obtains a sweet smelling, strictly saturated gasoline. This he accomplishes by a chemical reaction of quite different type from that of Burton or Rittman. He works at ordinary pressure and at quite moderate temperatures, say 500° F. He heats the oil to be cracked with a few per cent. of its weight of aluminium chloride. This chemical, aluminium chloride, reacts with the oil to give a coke-like carbon and low boiling hydro-carbons of the type designed for motor fuel. The one handicap has been that it has not proved possible economically to recover the aluminium chloride for reuse, and the selling price of gasoline has not been high enough to permit the throwing away of the chemical after one use.

Many an oil well gives at the same time considerable amounts of gas as well as oil. If this gas is examined it is found to be formed in part by the evaporation of the same volatile constituents as are present in the liquid petroleum. If we condense the low boiling liquids from this gas we will obtain a very volatile gasoline. Gasoline obtained from the gas coming from the top of the casing of an oil well is called in the industry "casing head gasoline." There are several methods of condensing this casing head gasoline. If an air compressor is taken and this used not to compress air, but to compress the gas coming off with the oil from the well it will be found that part of the gas is condensed to a liquid. This liquid when drawn off is found to be a desirable and highly volatile gasoline. In fact its volatility is so high and its density so low that it can be mixed with higher boiling constituents such as kerosene and the resulting product appear to be a gasoline of ordinary type.

Many times instead of depending on compression alone the compressed gas is bubbled through a high boiling solvent such as gas oil and the resulting solution of gasoline in the absorbent oil later distilled to recover the gasoline and absorbent oil for reuse.

In still other plants the absorption is not by means of a heavy oil but by absorbent carbon. Silica gel is a new material which promises to displace the absorbent carbon and gas oil for this purpose as it is a still better absorbent.

We have also found that many, but not all, of the natural gas wells, wells which furnish gas but no oil, carry considerable gasoline in the gas. Gas wells of West Virginia and of Pennsylvania in general are of this type. Gasoline can be recovered from these in the same way as it is recovered from the casing head gas of the oil well.

Whether recovered from the casing head gas of an oil well or from a straight gas well, the gasoline obtained is of such a character that at the present day it is most all used for blending purposes to bring the lower grade gasoline to a higher grade. The amount of this condensed gasoline available is minor as compared with the requirements of the country.

As I stated before the requirements for gasoline are increasing year by year by very considerable amounts. We, in this country, have had gasoline cheap and in comparative abundance. This has not been true the world over. We consider 40 cents a gallon high, but most of the world would welcome gasoline at 60 cents a gallon and call it cheap. Europe is using and has been using as a motor fuel for some time large amounts of benzol, obtained as a by-product from its coke and gas plants. The Scottish shale oil plants have been furnishing considerable quantities of a motor spirit from oil shale. Cuba has had a surplus of molasses; this molasses on fermentation giving alcohol, and Cuba has been making extensive use of this alcohol not only to furnish visitors from the United with a beverage, but also locally it has taken the place to a considerable extent of gasoline for automobile uses. Natal, of South Africa, has also an abundant supply of alcohol from its waste molasses. Imported gasoline is quite expensive and, accordingly, they have devised a product which goes by the name of Natalite, and which has largely taken the place of gasoline in that part of the world. This Natalite is a mixture of alcohol with about 45 per cent. of ether. In the United States we have

had but one commercial attempt to supply a gasoline substitute. This is the "alcogas" put out by the United States Industrial Chemical Company, of Baltimore, this company being a subsidiary of the United States Industrial Alcohol Company. Each of these substitutes has its advantages and disadvantages. Benzol is decidedly cheaper than gasoline in Europe, but on the other hand it is harder to start the engine than with gasoline. Shale motor spirit of Scotland often runs 60 per cent. unsaturated and, accordingly, it is strongly odored, somewhat colored and cannot be stored for any considerable time without loss of quality. The alcohol products of Cuba and Natal, particularly when mixed with ether, as in the case of Natalite, give trouble owing to their great tendency to make the engine "knock" and also some trouble due to the difficulty of obtaining them free from acetic acid. If acetic acid is present there will be corrosion of the storage tanks, tank cars and the container tanks in the automobile. This corrosion and also the "knock" effect can be reduced and even avoided entirely by adding such material as aniline, but aniline is expensive. One does not want to add any considerable amount of a constituent costing $1.50 to $2.00 a gallon, and aniline cannot be had for less.

The "alcogas" is a more complex material than the substitutes used in other countries. It consists approximately of one-third benzol distillate, principally benzol and toluol, a second third of alcohol products, alcohol and ether, and the remaining third of petroleum distillate, principally gasoline. The amount of ether required to easily start the engine varies according to the time of year. In winter 10 per cent., and in summer 3 per cent. is all that is essential. This American gasoline substitute has a big advantage over ordinary gasoline in that the cylinders do not carbonize. This keeping of the cylinders clean means ordinarily a greater (11 per cent.) mileage per gallon than is obtained from gasoline. On the other hand, the price of the product has been kept slightly above that of gasoline and the company making same is handicapped by the variation in the markets from time to time, of the supply and price of each of the three constituents. In other words, if the supply of benzol distillate on the market is small then it ceases to be practicable for them to put out any large amount of alcogas, no matter if they do have a surplus of the other constituents. Such an alcohol-ether mixture suffers, though not to the same extent as Natalite, with the tendency to "knock"

and to corrode the shipping containers and storage vessels. It is reported that the company have been studying this phase very carefully and that they expect soon to put out a product as free of corrosion troubles and "knocking" as good grade gasoline. I hope they will, for it will increase our supply of motor fuel and at the same time broaden the commercial outlet for benzol products and alcohol.

The petroleum requirements of the country are steadily increasing, the amount of the increase being approximately fifty million barrels a year. Part of this increase is due to the increase in fuel oil requirements, but a large part is also due to an increase in the gasoline requirements. Apparently the gasoline requirement of the country is going to continue to increase and perhaps at an even greater rate than in the past. This is well shown by the tables (page 318).

The prospects for an increased supply of petroleum from American oil wells are nil. The investigations of the United States Geological Survey and the United States Bureau of Mines show quite definitely that the United States is approximately at its peak of production, and that within a very few years, probably within three years, the production of petroleum in the United States from wells will begin to fall off. Moreover, the Geological Survey calls attention to the fact that we should not expect to find any more large fields of petroleum in the United States. In other words, that practically all of the possibilities in the way of large petroleum fields in this country have been well prospected, and that now we can calculate fairly closely what the production will be in the future. This calculation shows quite definitely that it is soon to decrease in amount. In the past, as at present, the United States furnished approximately two-thirds of the world's production. But we are consuming more than we are producing, for example, in 1919 the United States imported fifty-three million barrels from Mexico, and in 1920 one hundred and six million barrels. In 1921 the importation was twenty million barrels more than in 1920. In each year the United States has imported roughly about 60 per cent. of the total production of Mexico.

Mexican and Texas fields are short life type of fields, already they are in some places furnishing salt water instead of petroleum.

Four years ago a careful canvass of the situation showed that there was relatively little known about many of the fundamental

factors upon which a successful shale oil industry must be based. For example, almost nothing was known regarding the heat of reaction by which shale oil is formed from the organic material of the shale. Little was known regarding specific heats and latent heats, but nothing was known regarding the first reactions that

TABLE I.

U. S. Production Motor Vehicles.

	Passenger Trucks	Tractors
1916	1,493,617	116,670
1917	1,740,792	190,629
1918	926,388	359,947
1919	1,657,652	480,954
1920	1,883,158	525,246

Total number (9,500,000) in use in 1922 is nearly three times number in use in 1915.

TABLE II.

Barrels Crude Oil in U. S. (U. S. Geological Survey).

	Production	Consumption
1910	205,000,000	205,000,000
1912	225,000,000	225,000,000
1914	265,000,000	280,000,000
1916	300,000,000	320,000,000
1918	350,000,000	410,000,000
1919	377,000,000	418,000,000
1920	443,000,000	531,000,000

TABLE III.

U. S. Gasoline Production.

1917	2,850,000,000 gallons.
1918	3,570,000,000 gallons.
1919	3,960,000,000 gallons.
1920	4,880,000,000 gallons.

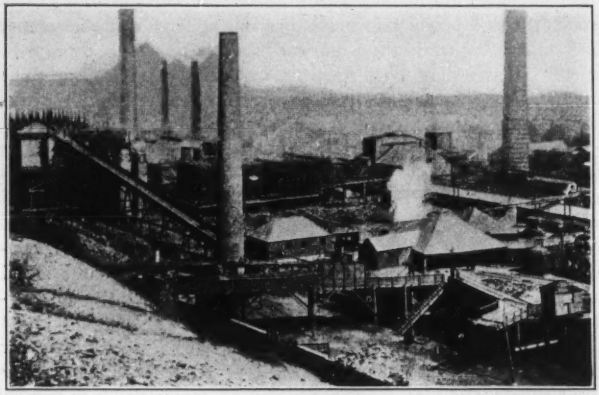
Of which 15 to 20 per cent. is produced by cracking and about 10 per cent. from casing head gas.

control the formation of oil from the organic material. In the thought that this was going to be an industry of great importance to the country and that the knowledge of the fundamental factors on which the industry is based were essential to a proper development of that industry, we undertook at Columbia University the study of these fundamental factors. I may add that since that time I have had four different graduate students working on various parts of these problems. A large part of this work is, of

course, yet incomplete, but results have been obtained that are of the utmost importance. It would take several evenings to discuss the methods used and the data obtained. To-night I can only give you results.

One of the most important factors entering into the design of a proper shale retort is that of the knowledge of amount of heat absorbed or evolved in the formation of shale oil from the organic matter of the shale. One of our men devised the first apparatus capable of directly determining this factor and found

FIG. 1.



General view of the Pumperston Shale Oil Plant.

that heat was absorbed in the process, and that the amount of heat absorbed was nearly the same for shales from different sections. This heat absorption amounted in general to about 450 calories per gram of oil and gas produced, or in other terms, 160 B.T.U. per pound of average shale retorted. This is a surprisingly low figure for such a reaction.

It has been generally thought that the organic matter in shale decomposed on heating to form petroleum products as the primary products of decomposition. It has been shown by these researches in the Chemical Engineering Department at Columbia University that this is not the case, but that the primary product of the decomposition is a heavy solid or semi-solid bitumen and that petroleum

is formed by a secondary cracking process from this semi-solid bitumen. This cracking process by which petroleum products are formed is a liquid phase cracking process similar to the well-known phenomena of the cracking of petroleum to give gasoline such as that of Burton.

Another surprising thing found was that the decomposition temperature of the shale to give the semi-solid bitumen was a quite definite temperature, one with 400° and 410° C. as its limits.

The investigations have also shown to be incorrect the belief which has been held by many of those working on the developments of shale oil manufacturing process, that on heating, gasoline is the first product formed; then on higher heating kerosene; and on still higher heating lubricating oils, etc. In other words, it was shown that what happens on heating is that all these products are formed *simultaneously* by the cracking of the semi-solid bitumen first formed.

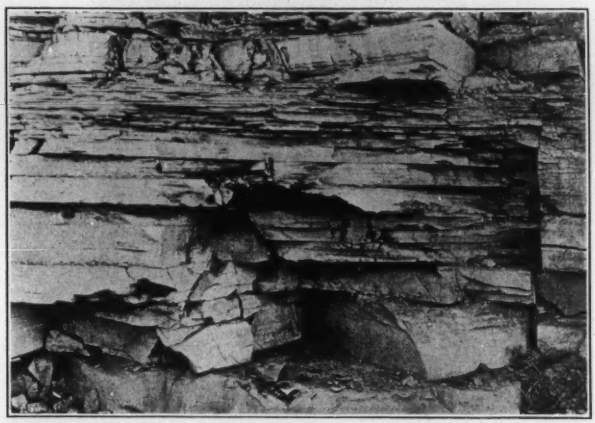
The true oil shale is a clayey or sandy, shaley deposit from which petroleum may be obtained by distillation, but not by treatment with solvents. Sometimes certain sand deposits are saturated with oil or asphalt. From these the oily constituents can be removed by solvents and, accordingly, are not commonly considered as true oil shales, but instead, go under the name of oil sands. Moreover, they are relatively small in extent and apparently have minor industrial possibilities.

Oil shales vary among themselves not only in yield of oil per ton of shale, but also in type of oil, type and character of minor constituents, and also even in the gangue material which carries the organic portion.

In Scotland they are working oil shales which furnish but 20 to 22 gallons of oil per ton of shale mined. In this country we have large deposits of shales which are able to give a much higher yield of oil. The largest of these deposits are the Green River shales of Colorado, Utah and Wyoming. There are also large deposits in Nevada, California, Kentucky, Indiana, Ohio, New Brunswick and Nova Scotia, and smaller deposits, though large enough for commercial exploitation, in many other portions of this continent. There are similar deposits in other parts of the world. Of these deposits which are likely to be exploited in the next decade, we have variations in yield from 20 gallons to 60 or even 80 gallons per ton. The large deposits of better grade will

give about a barrel (42 gallons) of oil per ton of rock. The character of oil produced in some cases is apparently a straight asphalt type petroleum similar to California well petroleum. Other shales give a large quantity of paraffin wax of even better quality than that given by the best oil wells of Pennsylvania's history. In the opinion of the speaker the average petroleum to be made from American oil shale will resemble most closely the

FIG. 2.



Massive shale, Utah.

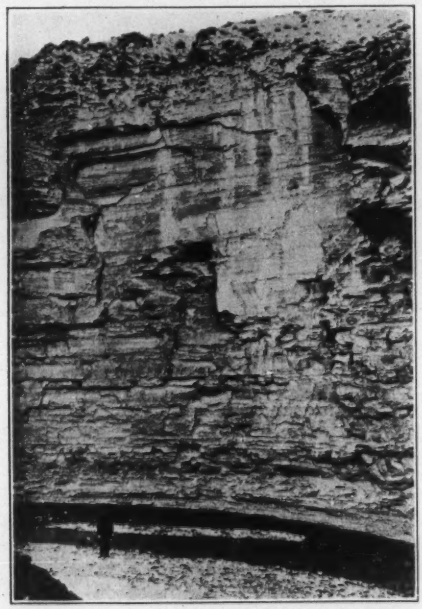
petroleum obtained from the present mid-continent field, such as the Oklahoma oil.

It is not commonly appreciated how large these oil shale deposits are. If we consider only those oil shales which will furnish a barrel or better of petroleum per ton of shale (a barrel is 42 gallons) we have in the Green River section alone in known deposits sufficient to furnish 64 thousand million barrels of petroleum. This is an enormous amount. It is eight times larger than the total of the well petroleum that this country has produced since Colonel Drake drilled the first oil well in 1859 at Titusville, Pennsylvania. It is more than five times the total production of the world since well petroleum became commercial sixty years ago.

If we are to have gasoline in quantity from shale oil we must

make the crude shale oil and then crack it by some one of the oil cracking schemes. By the most used present method of cracking, that used by the Standard Oil Company, the gasoline as made will not be one of high quality. It will be strong odored, will color on standing, and will be inclined to carbonize the cylinder.

FIG. 3.



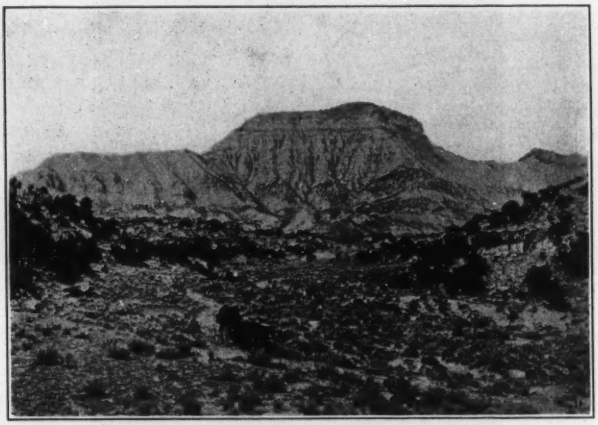
Oil shale cliff, Utah.

On the other hand, its heat value per gallon will be greater and, accordingly, in a properly designed motor it should give a slightly higher mileage than old fashioned gasoline. On the other hand, if we used the McAfee process of cracking, we would get stable, water white, well keeping, pleasant odored gasoline of the old type. However, it is to be remembered that the McAfee process is a more expensive type of oil cracking. At present in

Scotland they are using the ordinary scheme of cracking in which considerable quantities of unsaturated compounds are formed, as high as 60 per cent. This motor spirit is commonly used by the public and it is not considered by the general public in that country to be of lower grade than gasoline from well petroleum.

In distilling most oil shales to get petroleum there is formed simultaneously considerable quantities of ammonia from the nitrogen constituents of oil shale. This ammonia is usually

FIG. 4.



A mountain of shale, Colorado.

absorbed in sulphuric acid, recovered and sold in the form of ammonia sulphate for fertilizer uses.

A shale oil plant, then, to be successful, must be able to handle cheaply and efficiently large quantities of oil shale, distilling it to get the crude oil and ammonia and then crack and refine the crude oil to give a motor spirit useful commercially. The Scottish plants do this, excepting that they devote considerable attention to the recovery of paraffin wax, and it is only the oil left after the wax recovery that is distilled to give lubricating oils, gasoline and burning oils, or is cracked to give shale gasoline.

The Scottish shale retort is a retort of vertical pipe type. When we attempt to handle American oil shales in this retort we

find that they give trouble owing to the pieces of shale sticking together and sticking to the sides of the retort. This caking of the shale lumps stops the passage of the shale through the retort. For use on most American shales it is quite apparent that we must either modify this Scottish retort or devise

FIG. 5.

Paper shale, Colorado.

retorts on new lines. The Scottish retort is designed with the dual purpose of recovering ammonia from the shale and the obtaining of oils. With the American shales we have larger amounts of oil, but ordinarily distinctly less ammonia than is produced from the Scottish shale. In other words, the retort to handle the American oil shale *properly* must be one which gives its attention primarily to the production of oil in quantity and of

acceptable quality, and only secondarily to the production of ammonia. There are more than a score of retorting schemes which have been proposed by various American inventors. None of these has yet produced shale oil in large quantities. The most completely developed plant and process is that of the Catlin Shale Products Company, at Elko, Nevada. They have a plant which has produced approximately 100,000 gallons of shale oil. They have a small commercial refinery almost completed, and it is probable that the first shale oil and shale gasoline to be marketed in quantity in America will come from this plant. There are probably several other types of retorts which have been proposed for use in distilling oil shale which would, if given proper technical study and trials, develop into commercial processes. At present few except the inventor himself believe that any of these retorts is certain to be practicable when used on a large scale. The ideal process will be one permitting the operations to be carried through on a large scale with minimum labor and with the recovery of good yields of commercially utilizable products.

It is only within the last five years that serious attention has been given to the question of the development of a proper type of retorting still, and we have no reason to think but that well before the same length of time from now has passed we will have succeeded in obtaining a retorting scheme which can handle with low labor costs efficiently and economically American oil shales.

It is not commonly appreciated with how few men a manufacturing plant of chemical nature can be run. Generally speaking, in such processes labor is a minor factor, but in connection with most of the retorting processes yet proposed labor and power requirements are large and will be approximately one man per barrel of refined product, if mining as well as retorting and refining are included. This is the Scotch labor requirement, but we must reduce this labor requirement if we are to have in America a really successful shale oil industry.

I regret that the lateness of the hour forbids my discussing some of the other possible products from oil shale, such as the nitrogen bases which may yet supplant coal tar as a basis of a dye industry.

I have earlier shown you that the demands for petroleum are increasing in this country at the rate of about 50 million barrels a year. If this continues it will require each year seventy-five new

plants, each handling 2000 tons of oil shale a day and representing an investment of close to a million dollars each to give sufficient oil to meet simply this yearly increase in demands for petroleum. We have no other source of fuel oil or gasoline or gasoline substitute in prospect which promises to furnish even a minor part of this demand. In other words, we have reason to look forward to a very profitable chemical manufacturing industry which will rank with our largest manufacturing industries in its labor and capital requirements and in value of output.

On Friction When Lubricants are Employed. A. SOMMERFIELD. (*Zeit. für Tech. Phys.*, No. 3, 1921.)—In this report on the state of our present knowledge of the subject attention is directed to a series of important experiments conducted by Miss Jacob at Koenigsberg on the frictional laws for dry surfaces. Brass on brass and glass on glass were investigated. The brass was polished to the highest degree and the glass was dried in a special manner so that in both cases the presence of even the smallest dust particle was avoided. With ordinary surfaces the coefficient of friction is greater for the state of rest than it is after motion has begun, but for these clean surfaces it is the same in both instances. When one piece of solid with only an ordinarily clean plane surface rests on a similar surface that is gradually tilted, the upper piece begins to slide when a certain angle is reached and does not move at all until this angle is reached, while in the case of the specially cleaned surfaces there seems to be no lower limit to this angle. What might in the experiment be taken as the lower limit seemed to depend only on the fineness of the methods employed for detecting microscopic motions. Just as soon as there was the least trace of dirt on the surfaces the laws reverted to the usual forms. G. F. S.

A Demonstration Experiment in Photo-electricity. W. HALLWACHS. (*Phys. Zeit.*, 1918, page 194.)—H. Greinacher described the following experiment: A freshly cleaned surface of zinc is connected to a sensitive gold leaf electroscope and is illuminated from an arc lamp placed 20 cm. away. A strong current of air from a bellows plays on the zinc. At once the electroscope begins to show a positive charge which increases until a maximum potential of about 100 volts is attained. Without the light the air current produces no effect. Professor Hallwachs, of the Dresden Technical Institute, calls attention to his having published this same experiment twenty-eight years earlier and welcomes this confirmation of his own observation. In those early days of the photo-electric effect the real cause was not known. Now it is recognized that the light incident on the surface sets free electrons which, carrying off charges, leave the metal positive. G. F. S.

FOGS AND CLOUDS.* †

BY

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INTERNATIONAL DEFINITIONS AND DESCRIPTIONS OF CLOUD FORMS, AND SUPPLEMENTARY REMARKS.

1. Cirrus (Ci.).—*"Detached clouds of delicate appearance fibrous (thread-like) structure and feather-like form, generally white in color.* Cirrus clouds take the most varied shapes, such as isolated tufts of hair, *i.e.,* thin filaments on a blue sky, branched filaments in feathery form, straight or curved filaments ending in tufts (called *cirrus uncinus*), and others. Occasionally cirrus clouds are arranged in bands, which traverse part of the sky as arcs of great circles, and as an effect of perspective appear to converge at a point on the horizon and at the opposite point also if they are sufficiently extended. Cirro-stratus and cirro-cumulus also are sometimes similarly arranged in long bands." (Figs. 3, 4, 5, 6 and Figs. 68, 69 of *Physics of the Air.*)

An interesting form of cirrus clouds is the familiar "mares' tails" (Fig. 68, *Physics of the Air*), especially when a considerable number of them occur in the same region of the sky. These are only thin streaks of snow into which a little ball of rising cloud is drawn out, partly by the slow descent of the snow itself, and partly by the increase of wind velocity with elevation.

The cirrus occurs at greater heights than any other type of cloud—roughly 5 miles in polar regions, 7 miles in middle latitudes and 9 miles within the tropics. Since it occurs above all other clouds it also is the coldest, ranging from 50 degrees Fahrenheit below zero near the poles to 90 degrees below in the neighborhood of the equator, the difference in temperature

* Based on a lecture given before the Section of Physics and Chemistry of The Franklin Institute on January 5, 1922.

† Concluded from p. 230, vol. 193, February, 1922.

being due to the difference in height. Furthermore, because it is the coldest of the clouds it likewise is the thinnest, being formed in air whose water content, owing to its low temperature,

FIG. 3. Cirrus. (F. Ellerman, photo.)

must be very small. Indeed, the sun and moon are sharply outlined through it. Finally, as its temperature is so very low the cirrus nearly always (there seem to be occasional exceptions) consists of snow crystals.

As just stated, the cirrus occurs at higher levels than does any other type of cloud. But it also occurs, under favorable conditions, at any other level, even down to the surface. It is only a shallow,

FIG. 4. Cirrus. (P. Ellerman, photo.)

or thin, cloud of fine snow crystals (except rarely) drawn out by the wind into more or less parallel, fine streaks. Its chief cause appears to be the further cooling, by expansion due to ascent, of air already cold and holding but little moisture, and the dragging

out of the slight cloud thus formed into streaks and whirls by the winds in which it occurs.

When the cirrus slowly disappears, leaving a clear sky, fair

FIG. 5. Cirrus, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

weather is probable for at least a day or two. On the other hand, when it gradually thickens and merges into a nearly continuous and formless sheet, rain or snow usually begins within a few hours.

2. Cirro-stratus (Ci.-St.).—"*A thin sheet of whitish cloud;*

sometimes covering the sky completely and merely giving it a milky appearance; it is then called cirro-nebula or cirrus haze; at

FIG. 6.

Cirrus, merging into cirro-cumuli. (P. Ellerman, photo.)

other times presenting more or less distinctly a fibrous structure like a tangled web. This sheet often produces halos round the sun or moon." (Figs. 7, 8.)

The halos here referred to are of two kinds: (*a*) Those due to the refraction of light into rainbow colors on its passage through

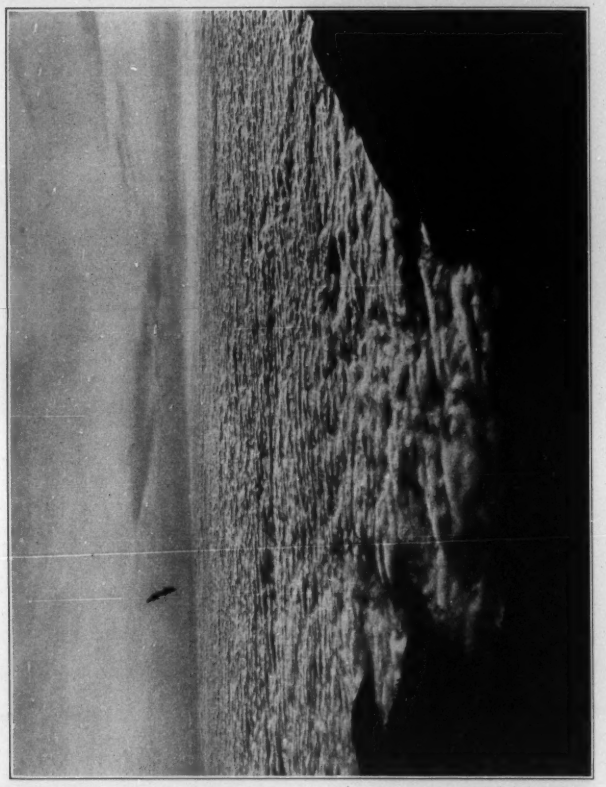


FIG. 7. Cirro-stratus, above; advection fog, below; seen from Mount Wilson, Cal. (P. Ellerman, photo.)

ice crystals; and (*b*) those produced by the mere reflection of light (hence white or colorless) by the faces of these crystals.

The most common of the first class of halos are: (1) The circle of 22 degrees radius about the sun or moon (Fig. 9); (2) the similar circle of 46 degrees radius; and (3) the circumzenithal

arc, a brilliantly colored arc having the point directly overhead as its centre, but appearing on the side next the sun only. The chief

FIG. 8.

Cirro-stratus, above; cumulus, below. (M. Mott-Smith, photo.)

halos of the second or reflection class are (1) the parhelic circle, a white band of light passing around the sky parallel to the horizon

and through the sun (Fig. 9); and (2) the sun pillar, a vertical column of white light extending directly above and below the sun.

These halos are positive proof that the cirro-stratus clouds, like

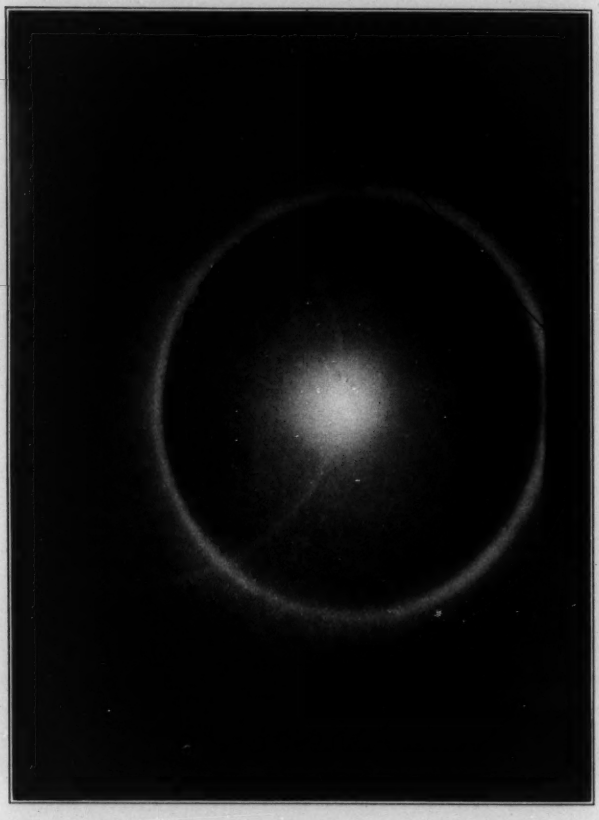


FIG. 9.

Halo of 22° and parhelic circle. (Contributed by A. M. Comey.)

the cirrus from which they frequently are developed, also consist, normally, of myriads of ice crystals.

Whenever the cirro-stratus cloud has developed from a cirrus

it may be assumed that rain or snow, as determined by the temperature, probably will soon follow, not out of the cirro-stratus, of course, but from an approaching nimbus, or rain cloud.

FIG. 10.

Cirro-cumulus. (E. E. Barnard, photo.)

Though denser than the cirrus, the cirro-stratus still is so thin as to leave the outline of the sun sharply defined.

3. Cirro-cumulus (Ci.-Cu.).—"*Mackerel Sky.—Small*

rounded masses or white flakes without shadow, or showing very slight shadow; arranged in groups and often in lines. French,

FIG. 11.

Cirro-cumulus, with alto-cumulus merging into stratus to the left, from the Ebro Observatory, Tortoso, Spain.

Moutons—German, *Schäfchen-wolken.*" (Figs. 10, 11 and Fig. 71, *Physics of the Air.*)

The term "mackerel sky" is an abbreviation of "mackerel-back sky," so named because of the frequent resemblance of rows of cirro-cumuli to the patterns (not the scales) on the backs of

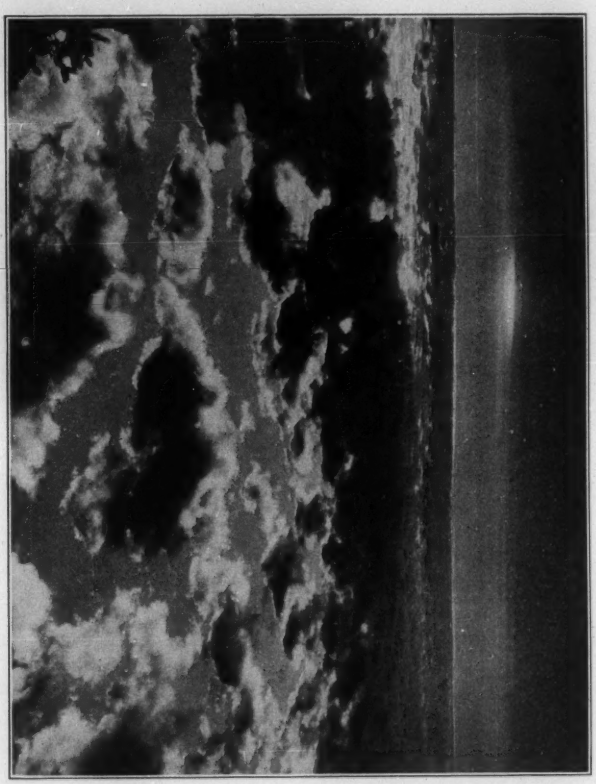


FIG. 12.

Alto-cumulus, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

one or more species of mackerel. When the cirro-cumuli are small, numerous and without order or pattern they often are called "curdle sky." (Fig. 11.)

All forms of the cirro-cumulus appear to be due to small local

convections. Those occurring in rows presumably are on the crests of air waves or billows at the interface between wind layers of unequal speeds or different directions, or both, and commonly

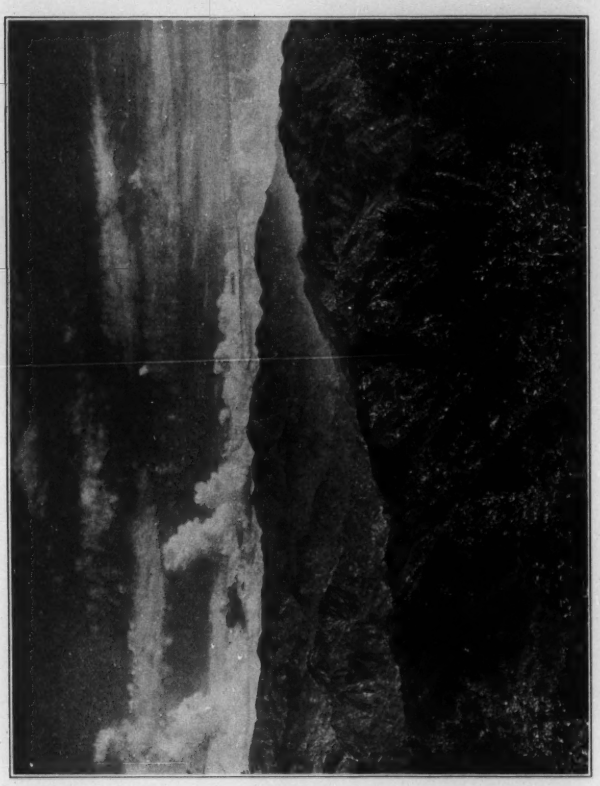


FIG. 13.—Alto-cumulus, turreted; and cumulus; seen from Mount Wilson, Cal. (P. Ellerman, photo.)

unequal also in temperature and humidity. The cirro-cumulus, through turbulence or other cause, often merges into a more or less uniform, stratified cloud, especially the cirro-stratus.

The fact that the cirro-cumuli cast but faint shadows, if any,

and that the sharp outline of the sun is visible through them shows that they are quite thin and contain but little cloud material.

4. Alto-cumulus (A.-Cu.).—"*Larger rounded masses, white or grayish, partially shaded, arranged in groups or lines, and often so crowded together in the middle region that the cloudlets join.* The separate masses are generally larger and more compact (resembling strato-cumulus) in the middle region of the group, but the denseness of the layer varies and sometimes is so attenuated that the individual masses assume the appearance of sheets or thin flakes of considerable extent with hardly any shading. At the margin of the group they form smaller cloudlets resembling those of cirro-cumulus. The cloudlets often group themselves in parallel lines, arranged in one or more directions." (Figs. 12, 13 and Figs. 73, 80, 81, *Physics of the Air.*)

The alto-cumuli appear to be due to local convections, caused either by differences of temperature or by wave motion, analogous to those that produce the cirro-cumuli, but are at lower levels, roughly two and one-half miles high, usually larger in volume and of more humid air. They frequently form in the early forenoon after a clear sunrise in consequence of scattered convection in a humid layer of air—humid from the evaporation in it of a previous sheet of alto-cumuli, or owing to moisture from the spread-out tops of thunderstorm clouds. After sundown this type of cloud frequently evaporates, through the process of cooling, contracting, and then sinking to a warmer and drier level.

5. Alto-stratus (A.-St.).—"*A dense sheet of a gray or bluish color, sometimes forming a compact mass of dull gray color and fibrous structure.* At other times the sheet is thin like the denser forms of cirro-stratus, and through it the sun and the moon may be seen dimly gleaming as through ground glass. This form exhibits all stages of transition between alto-stratus and cirro-stratus, but according to the measurements its normal altitude is about one-half of that of cirro-stratus." (Fig. 14, and Fig. 72, *Physics of the Air.*)

This type of cloud may be formed by the flow of warmer moist air over colder air beneath, by winds dragging out the tops of thunderstorm clouds, by the cooling in place of a layer of humid air, and by the relatively small precipitation out of alto-cumulus and cirro-cumulus.

The sun and moon when seen through the alto-stratus, alto-cumulus, or any other thin cloud of *water droplets,* are sur-

FIG. 14.

Alto-stratus, above; fracto-cumulus, below; across the Cauca Valley, Colombia. (P. M. Chapman, photo.)

rounded by one or more sets of rings of colored light commonly only two or three diameters of the sun, or moon, away.

These small circles, in which the red is farthest from the sun, or moon, are called coronae, and are produced, as just stated,

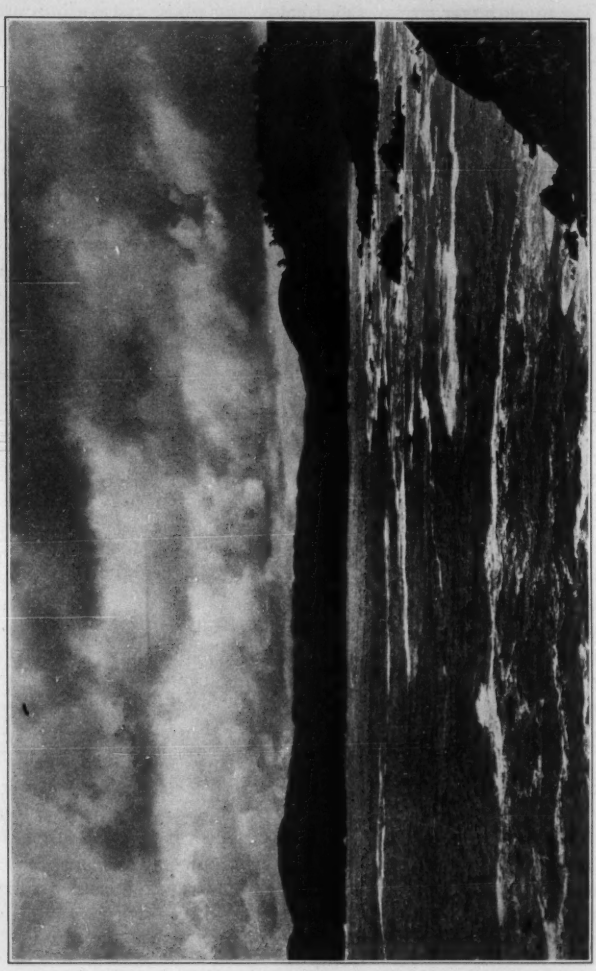


FIG. 15.

Strato-cumulus, Monterey Bay, Cal.

by the action (diffraction) of small water droplets on the light. The much larger circles, called halos, and whose red portions are nearest the sun, or moon, are caused, as previously explained, by the passage of light through *ice crystals*.

6. Strato-cumulus (St.-Cu.).—"*Large lumpy masses or rolls of dull gray cloud, frequently covering the whole sky, especially in winter.* Generally strato-cumulus presents the appearance of a gray layer broken up into irregular masses and having on the margin smaller masses grouped in flocks like alto-cumulus. Sometimes this cloud-form has the characteristic appearance of great rolls of cloud arranged in parallel lines close together. (*Roll-cumulus* in England, *Wulst-cumulus* in Germany.) The rolls themselves are dense and dark, but in the intervening spaces the cloud is much lighter and blue sky may sometimes be seen through them. Strato-cumulus may be distinguished from nimbus by its lumpy or rolling appearance, and by the fact that it does not generally tend to bring rain." (Fig. 74, *Physics of the Air.*)

This cloud, of which there are several forms ranging from the stratus of uneven density through the great parallel rolls to the sheet of well-nigh discrete cumuli, is always due to vertical convection. The more nearly discrete or separate masses are produced by the rising of warm air (thermal convection), while the irregularities in the stratus form appear to be caused, in large part at least, by mechanical turbulence. This last type (Fig. 15), might well be called turbulo-cumulus. The shallow depth, and broad expanse, of the strato-cumulus often is due to an overlying layer of air of such temperature that the rising, cloud-laden column can not pass through it, and hence is forced to spread out, much as rising smoke in a room spreads out under the ceiling.

7. Nimbus (Nb.).—"*A dense layer of dark, shapeless cloud with ragged edges from which steady rain or snow usually falls. If there are openings in the cloud an upper layer of cirro-stratus or alto-stratus may almost invariably be seen through them.* If a layer of nimbus separates in strong wind into ragged cloud, or if small detached clouds are seen drifting underneath a large nimbus (the '*Scud*' of sailors), either may be specified as *fracto-nimbus* (Fr.-Nb.)." (Fig. 16.)

The name of this cloud has evoked much discussion. Nimbus, originally meaning cloud and, inferentially, storm, now means snow or rain cloud. Hence many argue if rain, or snow, is falling from

FIG. 16. Nimbus, above; fog, below; seen from Mount Wilson, Cal. (F. Ellerman, photo.)

a cloud it certainly is a rain cloud. Likewise, if rain is not falling from it, then clearly it must be some other sort of cloud. But, on the other hand, if a given cloud while raining happens to be a typical rain cloud (nimbus) what was it immediately before we saw the

rain? Again, if it happens to be raining very hard what shall we call the cloud that we can not see for the rain? Suppose that we can not see the edge of the cloud that is raining, and generally we

FIG. 17.

Stratus, above; fracto-stratus, scud, or steam cloud, below. San Gabriel Range, Cal.

can not, dare we then call it a nimbus in face of the official definition "with ragged edges"?

These are typical of the questions and quibbles the arbitrary official definition of "nimbus" has evoked.

As a matter of fact a trace at least of precipitation may be falling from a typical alto-stratus, alto-cumulus, or other form, which it would be but confusion to call nimbus. Similarly, a

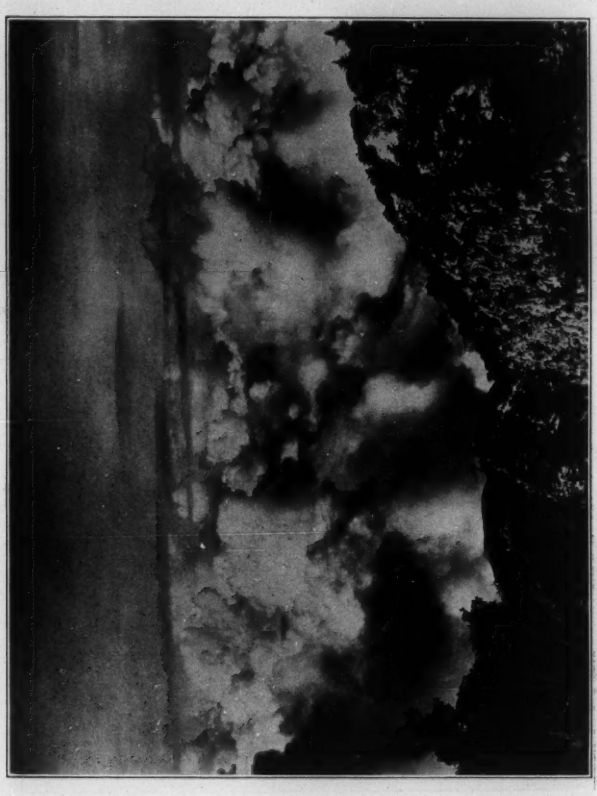


FIG. 18.

Cumulus, forming from fog—rare, seen from Mount Wilson, Cal. (P. Ellerman, photo.)

typical nimbus from which rain is falling steadily looks but little different from what it did immediately before the rain began. Hence it is convenient to interpret the definition broadly enough to cover both cases. If the cloud is typically alto-cumulus, call it alto-cumulus, whatever may be falling. On the other hand, if it looks

like a rain cloud and is not a "cumulo-nimbus," described below, call it nimbus, whether it is raining or not and regardless of all edges.

FIG. 19. Cumulus, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

Of course in taking weather notes it commonly is superfluous to say both rain and nimbus cloud, because the former nearly always implies the latter, except in the case of the thunderstorm, which is separately reported. However, if one were noting clouds

alone he certainly should say nimbus, or, occasionally, nimbus cumuliformis, whenever there is precipitation of appreciable intensity without lightning or thunder.

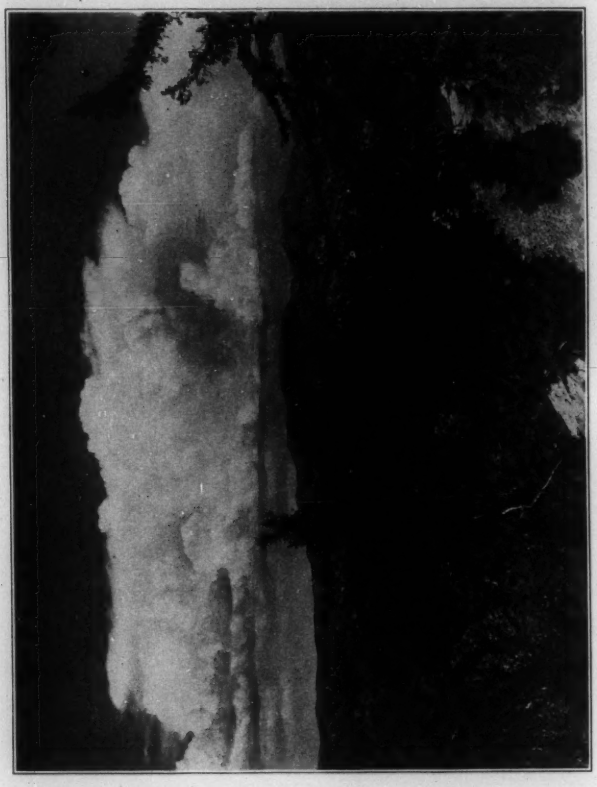


FIG. 20.—Cumulus, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

This type of cloud is most frequently formed by some kind of mechanical convection, such as ascent due to converging winds, the flow of air over mountain barriers, and the over and under running of currents of different temperatures.

The fracto-nimbus, or scud, is only a low, ragged detached fragment of cloud that often rises, like steam, immediately after rainfall on a warm surface, especially the sides of mountains, which

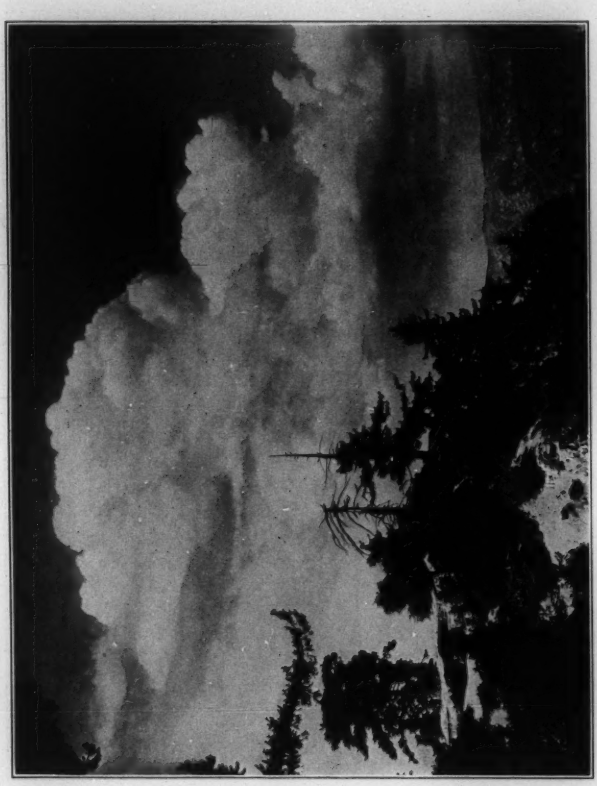


FIG. 21. Cumulus, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

it ascends like drifting fog. (Fig. 17.) It also is frequently dragged out of a crest cloud (which see below), by the swirls of the passing wind and hurled down the leeward mountain slope.

8. Cumulus (Cu.).—"*Woolpack or Cauliflower Cloud.*—

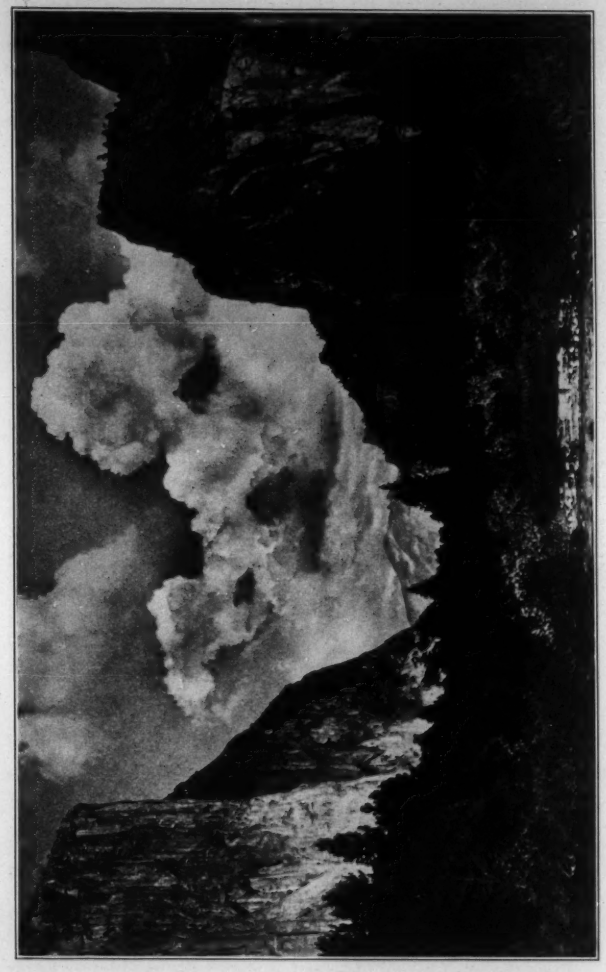


FIG. 22.

Cumulus, Yosemite National Park, Cal.

Thick cloud of which the upper surface is dome-shaped and exhibits protuberances while the base is generally horizontal. These clouds appear to be formed by ascensional movement of air in the daytime which is almost always observable. When the cloud and the sun are on opposite sides of the observer, the surfaces facing the observer are more brilliant than the margins of the

FIG. 23.

Cumulus, seen at Williams Bay, Wis. (E. E. Barnard, photo.)

protuberances. When on the contrary, it is on the same side of the observer as the sun it appears dark with bright edges. When the light falls sideways, as is usually the case, cumulus clouds show deep shadows." (Figs. 13, 18, 19, 20, 21, 22, 23.)

"True cumulus has well-defined upper and lower margins; but one may sometimes see ragged clouds—like cumulus torn by strong wind—of which the detached portions are continually changing; to this form of cloud the name *fracto-cumulus* may be given." (Fig. 78, *Physics of the Air.*)

Even the most casual observation shows the cauliflower heads

and sides of cumuli to be in a state of rapid change and constant turmoil. All clouds of this type are caused by the lower air being so much warmer than the upper that it is forced to ascend much as

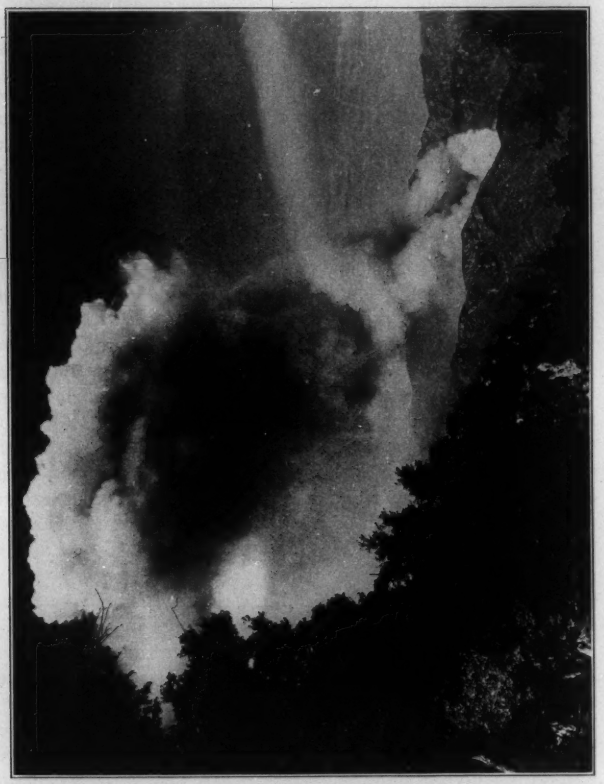


FIG. 24.—Cumulus formed by convection over fire, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

warm air is pushed up a chimney by the heavier cold air on the outside. Hence even forest fires sometimes cause the formation of cumuli. (Fig. 24 and Fig. 76, *Physics of the Air*.) However, we should remember that the fire itself adds a surprisingly large

amount of moisture to the air—a gallon of water, roughly, for every fifteen pounds of fuel burned, so that the fire cumulus is not entirely due to convection.

Since cumuli are caused by rising air currents induced by relatively high surface temperatures, they are very common in equatorial regions, and also through the middle latitudes during summer. Hence, too, they commonly occur over land most frequently during the afternoon and over water late at night. For the same reason they often follow a coast line, over the water at night and over the land through the day. Similarly, they are common over islands (Fig. 77, *Physics of the Air*), whose presence frequently is shown in this way while they themselves are still below the horizon.

9. Cumulo-nimbus (Cu.-Nb.).—"*The Thunder Cloud; Shower Cloud.—Great masses of cloud rising in the form of mountains or towers or anvils, generally having a veil or screen of fibrous texture (false cirrus) at the top and at its base a cloud mass similar to nimbus.* From the base local showers of rain or snow, occasionally of hail or soft hail, usually fall. Sometimes the upper margins have the compact shape of cumulus or form massive heaps round which floats delicate false cirrus. At other times the margins themselves are fringed with filaments similar to cirrus clouds. This last form is particularly common with spring showers. The front of a thunderstorm of wide extent is frequently in the form of a large low arch above a region of uniformly lighter sky." (Figs. 25, 26 and Figs. 75, 79, *Physics of the Air.*)

This is the most turbulent and also the thickest of all clouds, ranging in depth commonly from one to three miles and occasionally, in tropical regions, even to eight or nine miles (Fig. 112, *Physics of the Air*). Its times, places and modes of occurrence are all the same as those of the cumulus, given above.

10. Stratus (St.).—"*A uniform layer of cloud-like fog not lying on the ground.* The cloud layer of stratus is always very low. If it is divided into ragged masses in a wind or by mountain tops, it may be called *fracto-stratus.* The complete absence of detail of structure differentiates stratus from other aggregated forms of cloud." (Fig. 17.)

The stratus is the lowest of clouds, averaging round 2000 feet

above the surface. It frequently is formed by the lifting of relatively warm humid air by under running cold winds; by the flow of a warm humid wind over a surface stratum of cold air;

FIG. 25.—Cumulo-nimbus, Pensacola, Fla. (Lieut. W. F. Reed, Jr., photo.)

and by the drifting of deep fog from the sea over relatively warm land, as in the case of the "velo" cloud of southern California in which the lower portion of the fog is delightfully evaporated away

while the upper part is left as a gracious veil that shields one from the sun until nearly noon.

The same pamphlet, entitled "Cloud Forms," from which the

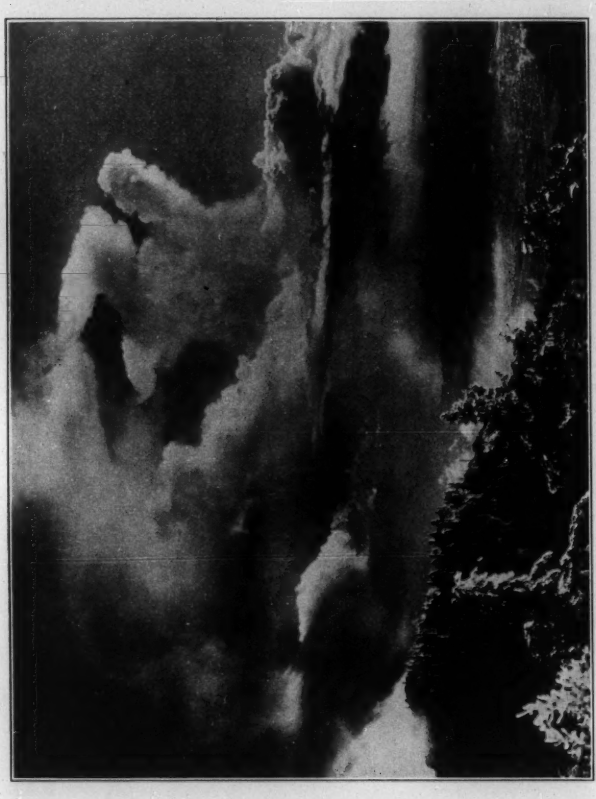


FIG. 26.

Cumulo-nimbus, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

above quoted definitions and descriptions of the ten standard cloud types were taken, contains also the following instructions to observers:

"(*a*) In the daytime in summer all the lower clouds assume,

as a rule, special forms more or less resembling cumulus. In such cases the observer may enter in his notes '*stratus-* or *nimbus-cumuliformis.*'

"(*b*) Sometimes a cloud will show a mammillated surface and the appearance should be noted under the name *mammato-cumulus.* (Fig. 88, *Physics of the Air.*)

"(*c*) The form taken by certain clouds particularly on days of sirocco, mistral, föhn, etc., which show an ovoid form with clean outlines and sometimes irisation, will be indicated by the name *lenticular,* for example: *Cumulus lenticularis, stratus lenticularis* (Cu.-lent., St.-lent.).

"(*d*) Notice should always be taken when the clouds seem motionless or if they move with very great velocity."

SPECIAL CLOUD FORMS.

It may seem, no doubt, that enough cloud forms have already been mentioned to include every type known to the heavens, and thus to satisfy the most ardent cloud observer, but, in addition to the gradual transformation of a cloud from one type to another, giving stages that puzzle the expert, there are several occasional forms sufficiently distinct, even though some of them belong to the general types already mentioned, to justify individual names and special descriptions.

Billow Cloud.—Billow clouds (Fig. 80, *Physics of the Air*), also called windrow clouds and wave clouds, occur in nearly equally spaced parallel bands, generally with intervening strips of clear sky. The billow cloud most frequently, perhaps, is only a special form of the more general alto-cumulus. It also is a common form, rather as ripples, however, of the cirro-cumulus. On rare occasions it likewise occurs at low levels where it might be called a type of strato-cumulus.

But whatever its level the billow cloud is always produced in the same way—by the flowing of one stratum or current of air over another of distinctly greater density, thereby creating air billows precisely as water billows are formed on the ocean. Now, the crests or tops of these waves are cooled by expansion, having risen above their previous level, and their troughs or bottoms warmed by compression. Hence, when the under layer is practically saturated, each crest, because of this cooling, is cloud-capped, and each trough clear.

It is particularly interesting to note that although each billow cloud maintains its identity and position in the series of waves as long as it exists at all—for hours it may be—nevertheless the

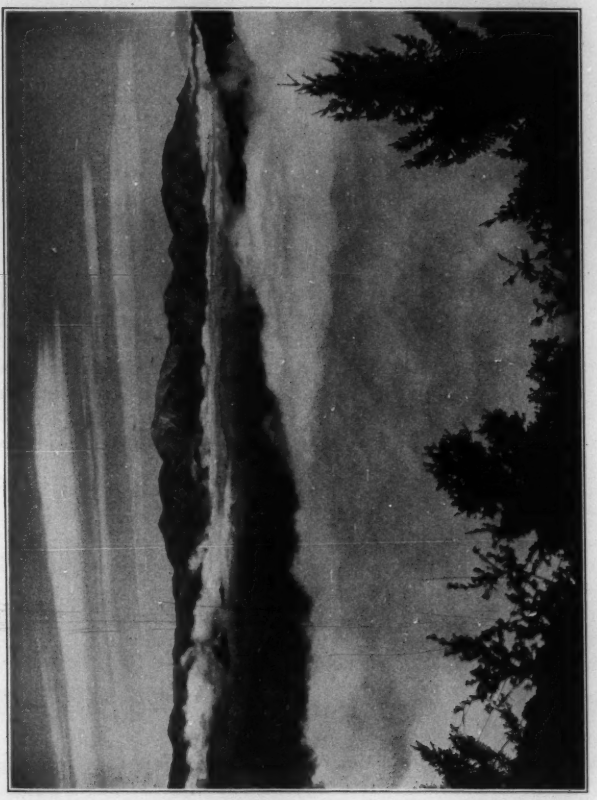


FIG. 27. Lenticular cloud (alto-stratus lenticularis), seen from Mount Wilson, Cal. (F. Ellerman, photo.)

actual particles of which it consists at any instant have only the briefest duration, there being continuous condensation on the rising or windward side of the billow and equivalent evaporation in the descending or leeward portion.

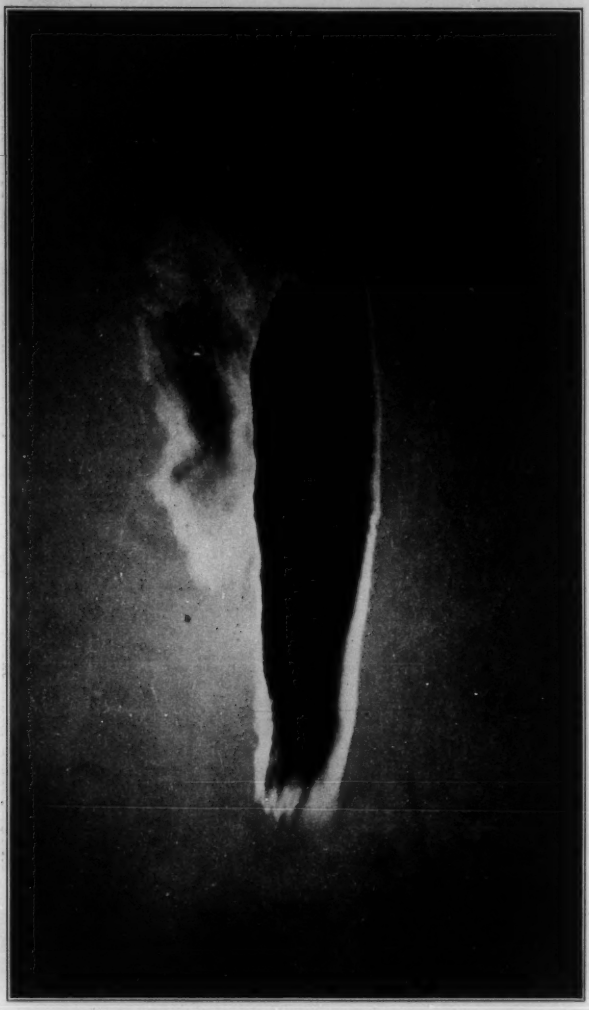
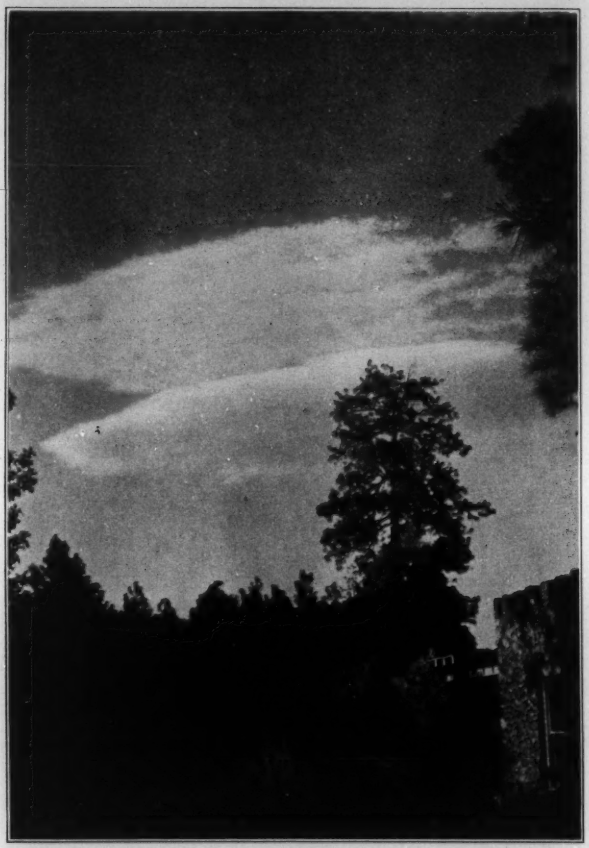


FIG. 28.

Lenticular cloud (cumulus lenticularis). (C. F. Brooks, photo.)

FIG. 29.



Lenticular cloud (cumulus lenticularis), seen at Flagstaff, Ariz. (C. O. Lampland, photo.)

Furthermore, while the billow cloud progresses steadily across the sky its velocity is neither that of the upper stratum nor of the lower, any more than the velocity of a water wave is either that of

the wind that is producing it or of the water in which it occurs. Wind velocity, therefore, can not be determined by measurements on clouds of this kind; nor, of course, by attempted measurements on any of the stationary types, such as those mentioned below.

FIG. 30.—Lenticular cloud, over Mount Shasta. (C. A. Gilchrist, photo.)

Lenticular Cloud.—The lenticular cloud (Figs. 27, 28, 29, 30 and Figs. 82 and 83, *Physics of the Air*) is only the cloud cap to a stationary or nearly stationary air billow produced as a rule by the flow of the wind over an uneven surface. It is especially

common among high peaks and rugged mountains. Its material, like that of the crest cloud, is in rapid change—condensation on the windward side and evaporation to the leeward. Hence it is shaped like a double convex lens, the suggestive origin of its name, thickest in the middle and thinning away to nothing on either side.

As implied above this is a stationary cloud, and hence one of the several that cannot be used to measure wind velocities.

Crest Cloud.—The crest cloud (Figs. 84, 85, *Physics of the Air*) is caused by the upward deflection, and consequent cooling by expansion, of humid winds by a long mountain ridge, whose crest it commonly covers, whence its name, and whose sides it often gracefully drapes. Occasionally, however, it forms slightly above and a trifle to the leeward of the ridge along the topmost (hence coolest) portion of the deflected wind current. In either case the cloud is permanent in position only, being continuously created (condensed) on the windward or ascending and cooling side, and destroyed (evaporated) on the lee or descending and warming side.

The best known example, perhaps, of this interesting cloud is the celebrated "Table Cloth" of Cape Town pride, spread by the southeasterlies over the top and down the sides of Table Mountain.

When the obstruction is only a peak the crest cloud is apt to be called a cap, hat, cowl, hood, and the like, all of which are recognized signs of bad weather, as, for instance:

"When Falkland Hill puts on his cap,
The Howe o' Fife will get a drap.

"When Traprain puts on his hat,
The Lothian lads may look to that.

"When Rubenslaw puts on his cowl,
The Dunion on his hood,
Then a' the wives of Teviotside
Ken there will be a flood."

Riffle Cloud.—Very often the crest cloud along a mountain ridge is paralleled by a similar but smaller cloud over the leeward valley, or plain in the case of the exceptional isolated mountain. The wind, deflected in a great wave over the mountain, rises in a series of decreasing billows beyond, like the waves or riffles in a river due to a ledge or rock or other obstruction on the bottom—hence the name "riffle cloud."

The process by which the crest cloud is formed along the ridge of the mountain and restricted thereto, that is, the cooling of the air by ascent on the windward side and its warming by descent on the lee side, occurs also in the rising and falling air on the windward and lee sides respectively of the series of air waves, or giant riffles, induced by the mountain obstruction to the wind. Hence, when the crest cloud is at all heavy the top of the first and largest wave is apt to be clouded; even the second wave occasionally shows some cloud, but the third rarely if ever.

The crest cloud and the riffle cloud, since they show the presence of humid winds, are excellent signs of rain, or snow, in a few hours. The order of occurrence is: Formation of the crest cloud; thickening of the crest cloud and forming of the riffle cloud; growth and union of these two clouds and the complete covering of the sky; onset of rain or snow.

Banner Cloud.—The banner cloud (Fig. 86, *Physics of the Air*) suggests a great white flag, whence its name, floating from a tall mountain peak. In strong winds the atmospheric pressure to the immediate leeward of such a peak is more or less reduced. If the humidity is right this causes a cloud through the resulting cooling, aided, no doubt, in many cases, by the cold walls of the peak itself. Here too, as in the preceding cases, the cloud is stationary, but its substance in rapid flux through condensation on one side and evaporation on the other.

Scarf Cloud.—It occasionally happens that as a cumulus rises rapidly to a great height a thin cirrus-like cloud arch, convex upwards, forms above, and detached from, the tipmost cumulus head (Fig. 31), so suggestive of a halo as to arouse poetic if not even pious fancies. As the cumulus continues to rise this flossy cloud grows and rests like a veil over the thunder head. A little later, a few minutes at most, it mantles the cumulus shoulder (Fig. 87, *Physics of the Air*), the head or heads being free, and may even drape the sides. In all cases it has the sheen and apparent texture of a great silken scarf—hence the name. It has often been called false cirrus, but that term is now commonly restricted to an entirely different cloud. It frequently is also called a cap cloud, but this name, apart from being loosely applied to any sort of cloud on a mountain peak, is applicable, by analogy, only during the early stages of the development of the scarf cloud and hence neither distinctive nor properly descriptive.

FIG. 31.

Scarf cloud, over cumulus, at Mount Ranier, Cal. (C. A. Gilchrist, photo.)

It is caused by the rising and consequent expansion and cooling of the air directly above the cumulus heads. Ordinarily this

movement and cooling of the air over the cumulus produces no visible effect. Occasionally, however, there happens to be a stratum of air at a considerable height (three or four miles) that

FIG. 32. Tonitro-cirrus (false cirrus), over the Valley of Va. (A. J. Weed, photo.)

is practically saturated. When such a layer is lifted locally, as just explained, a thin cloud, the first stage of the scarf cloud, is formed at the place of disturbance. When this layer is thin, as it com-

monly is, the thunder heads generally pass quite through it into drier air above, leaving the scarf cloud mantling the shoulders of the cumulus, or draping its sides at about the original level of the humid stratum.

Although this is not a rare cloud, few, apparently, are familiar with it, owing to its ephemeral nature and occurrence with other clouds. It has, of course, but little of the grandeur of a towering cumulus or intricacy of a far flung cirrus, nevertheless, its

FIG. 33.

Funnel cloud (tornado cloud), seen near Elmwood, Nebr., April 6, 1919.
(W. A. Wood, photo.)

coming into existence at an unexpected place, its silken texture, and its changes in form and position all merit its being carefully looked for and closely followed when found.

Tonitro-cirrus.—The name "tonitro-cirrus," thunder cirrus, is applied to those gray locks, to speak figuratively, combed out from old thunderheads by the upper winds, and also the thinner edges of the *anvil cloud,* or spreading top of a cumulo-nimbus. (Fig. 32.)

Even though the winds of the lower atmosphere are always light when great towering cumuli are formed, the upper winds may still be strong. Clearly, then, the top of a cumulus that extends into a stratum of swift winds is certain to be drawn out

into a more or less extensive, fibrous sheet of snow crystals that differs but little, if any, from the ordinary cirrus except in its mode of origin. A more common name for this cloud is "false cirrus," but this term is objectionable since the cloud in question is indeed a cirrus, differing from other cirri, as stated, only in origin.

FIG. 34.

Funnel cloud (tornado cloud), from two exposures taken close together, upper one first, seen near Elmwood, Nebr., April 6, 1919. (G. B. Pickwell, photo.)

Mammato-cumulus.—The mammato-cumulus, called also pocky-cloud, festoon-cloud, sack-cloud, "rain balls," and several other local names, is a sort of miniature up-side-down cumulus (Fig. 88, *Physics of the Air*). It occurs most frequently in connection with severe thunderstorms, and appears to be due to irregular descents here and there of cold air onto an existing

stratus cloud, each place of fall being marked by a downward bulge in the cloud base.

Tornado or Funnel Cloud.—The tornado or funnel cloud (Figs. 33, 34, 35) is only a long funnel shaped cloud about the axis of rotation of a tornado. It hangs down, either straight or curved, from the base of a rain cloud—commonly if not always, a cumulo-nimbus—and varies in extent all the way from a mere protuberance on the parent cloud, to a crooked trunk reaching all the way to the earth. It is caused by the cooling, due to expansion, of the rotating air, to a temperature below the dew-point. In short, it is just cloud, induced, like other clouds, by cooling, though often mixed with dust in its lower portion.

CLOUD MISCELLANY.

CLOUD MATERIAL.

Clouds consist either of water droplets, always when the temperature is above freezing, or ice crystals, normally when the temperature is below freezing, but not invariably, because occasionally the droplets cool even much below the "freezing point" without solidifying.

The droplets that together constitute a cloud out of which no rain is falling vary in size from the vanishingly small, especially at the surface and edges where they are likely to be disappearing by evaporation or coming into existence through condensation, up to several fold that of the average particle. Most of them, however, appear to be about one one-thousandth of an inch in diameter, roughly the size of the familiar lycopodium spore. In rain clouds, on the other hand, such as the cumulo-nimbus, this range is much greater—from the invisibly minute, as before, up to the fully developed drop of, say, one-tenth to one-eighth of an inch across.

The ice crystals, the material of cold clouds, also vary widely in size, and include every gradation from the minute, almost microscopic, needles of the cirrus to the well-known snow flakes of the winter storm. Their chief claim, however, on our attention is not because of this interesting dimensional range, but owing to their exquisite beauty. The fundamental pattern, however simple or complex the crystal, is always the same, the hexagon, or six-sided column (Fig. 160, *Physics of the Air*), but the variety is endless:

FIG. 35.

Funnel cloud (tornado cloud).

Needles with pyramidal ends; columns, with flat ends; mere hexagonal flakes; hexagons with a simple extension at each angle,

and hexagons with complex extensions in myriad varieties—and all are beautiful. Naturally then, hundreds of these numberless forms, as admirably photographed by that enthusiast, Mr. W. A. Bentley, of Jericho, Vermont, have been used as models in design and art. Nor is there a keener zest than Mr. Bentley's as year after year he adds pattern upon pattern to his long since marvellous collection of photomicrographs of the snow crystal.

WHY THE ATMOSPHERE AS A WHOLE NEVER IS SATURATED.

Since evaporation is continuous from much the greater portion of the surface of the earth it would seem that the atmosphere would soon become saturated throughout, and perhaps even filled everywhere with fog and cloud. But before the surface air has become approximately saturated to any considerable depth it commonly is carried to higher levels by some type of convection, and this causes it to cool, as already explained, and eventually to give up much of its moisture, generally in the condition of rain or snow. Sooner or later, however, the air out of which the precipitation falls returns to lower levels where clearly it is less humid, on the average, than when it began to ascend by the amount of water abandoned during its upward course. In short, vertical convection induces precipitation through cooling, and precipitation in turn so dries the air as to prevent it from becoming and remaining everywhere intolerably humid, as it otherwise would be.

WHY CLOUDS FLOAT.

Since water is about 800 times heavier than air one might well wonder how it is possible for a cloud, consisting of myriads of droplets, to float in a medium so light and of such slight resistance to penetration as the atmosphere. But, however imperceptible and entirely negligible the resistance of still air may be to our own movements, it is not strictly zero. In vacuo, for instance, as we know from one of the most familiar of experiments, "the farthing and the feather fall together," but more and more apart in air of increasing density. Now the total pull of a raindrop, say, causing it to fall, remains the same no matter how finely it is divided, while the amount of air disturbed, and hence the resistance and time of fall, increase with every subdivision; and since a single raindrop, one-sixth of an inch in diameter, is divisible into, or is the equivalent of, eight million average cloud droplets, it is clear

that, while the rain may descend, the cloud must settle, if it comes down at all, much more slowly.

Cloud droplets of the size just implied, that is, such that twelve hundred of them side by side make a row one inch long, do, as a matter of fact, fall through still air about eight feet per minute. Hence, where there are no rising currents, a cloud must, and does, gradually sink into the lower unsaturated air and evaporate. Clouds, however, as explained above, commonly are formed in ascending currents, and this ascent generally is distinctly greater than eight feet per minute, the rate just given of cloudfall in still air. Hence cloud is continuously formed at that level at which the rising air is cooled by its expansion to the dew-point. The droplets here formed are carried to higher levels, there evaporated or merged into raindrops, or carried away, as circumstances determine, but new droplets replacing these are as continuously being formed as fresh humid air arises to the cloud-level.

Clouds, therefore, do not even eventually fall to the earth because either they are continuously formed at the condensation level by rising currents or, on slowly sinking (eight feet per minute) to lower levels in still air, or being dragged down by descending air, are soon evaporated. In any case the cloud floats at a greater or less height and never falls precipitately to the earth as does rain.

HOW RAIN IS PRODUCED.

Few people ever ask how rain is produced. Perhaps this is because the phenomenon is too familiar to arouse one's curiosity or make him in the least inquisitive. Nevertheless, and however childish it may seem, it is both a rational question and a difficult one to answer.

The familiar, pretended answer, is, in effect, that somehow the air is cooled until condensation occurs on the various nuclei present, and that the larger of the droplets thus produced that happen to be well up in the cloud fall to lower levels, thereby encountering many other particles and through coalescence with them growing into full-sized drops. But, as implied, this explanation explains nothing. In the first place there are so many nuclei present in the atmosphere—hundreds at least, and usually thousands, to every cubic inch—that division of the condensed vapor between them leaves every one quite too minute to fall with any considerable velocity. Then, too, calculation shows that if a

particle should fall, in the manner supposed, through a cloud even a mile thick and pick up everything in its path it still would be a small drop. That is, rain is not formed in this simple manner, as is also obvious from the fact that a cloud may last for many hours without giving any rain whatever.

The actual processes in the formation of rain seem to be:

1. For some reason, such as surface heating, a mountain in the wind's path, or convergence of different currents, the surface air is forced up to considerable heights; during which rise it does work—gives up energy—by expansion against the surrounding pressure and thereby cools.

2. As soon as the dew-point is passed condensation begins on the innumerable nuclei present and a cloud is formed, the particles of which, being heavier than equal volumes of air, slowly fall with reference to the atmosphere itself. That is, the rising current passes by the cloud particles to a greater or less extent however high they may be carried.

3. The lower cloud particles filter the air rising through them and thereby more or less clean it of dust motes and other nuclei. Hence the droplets formed in the rising air after this filtration grow much faster, being relatively few, than they otherwise would.

4. Presently many of the larger droplets coalesce and thus become heavy enough to fall against the rising current. Nor, indeed, can they fall (reach lower levels) until by condensation, or coalescence, or both, they have attained a certain minimum size determined by the vertical velocity of the air in which they happen to be.

In short, a rising current, essential to any considerable condensation, that sustains, or even carries higher, cloud droplets until they have grown to falling size, and the automatic filtering of the ascending air by the cloud formed in it (which filtering restricts further condensation to comparatively few particles and thus insures their rapid growth), appear to be necessary and sufficient to account for the formation of rain.

5. Most of the drops, as they emerge from a cloud, are likely to have substantially the same size, namely, that which is just sufficient to overcome the upward movement of the air in which they were formed. Now, drops of the same size fall with the same speed, hence any two that happen to be close together are likely to remain so much longer than drops of unequal size and

thereby have more chances of union through fortuitous disturbances. Furthermore, when falling drops are side by side the air tends to push them together just as passing boats are forced toward each other. Clearly, though, this pressure has time to bring closely neighboring drops into actual contact only when they fall with the same, or very nearly the same speed. From these considerations it seems that the smallest drops, size 1, say, should unite to form size 2, and size 2 unite with each other to form size 4, rather than with size 1 to form size 3, and so on, doubling at each union. Hence we should expect more drops having the weights 1, 2, 4, 8, ... than any intermediate values, and this expectation has been fully verified by observations on all sorts of rains.

THE MEASURING OF CLOUD HEIGHTS.

It is always interesting and sometimes very useful to know the heights of the clouds, or, to be more exact, the heights of their bases—useful, frequently, to the aviator to whom very low clouds may be a danger and certainly a nuisance, and useful as an aid in forecasting the local weather for the next few hours.

There are several methods of determining the heights of clouds as accurately as ever is necessary. Indeed, under favorable circumstances, the error may not be more than a few feet.

1. The aviator, for instance, can take the reading, corrected if necessary, of his altimeter the instant he climbs into the base of a cloud.

2. A pilot balloon (small free balloon without instruments) may be observed from two stations a mile, say, apart, and its exact direction from each station, both horizontal and vertical, noted as it disappears into a cloud base. From these directions, which can be determined very accurately with suitable theodolites, and from the known distance between the two observing stations and the height of either above the other, the cloud height is readily obtained by a simple trigonometrical calculation.

3. Any definite spot on the base of a cloud may be simultaneously observed (triangulated, to be exact) from the two stations and its height calculated from the data thus obtained, precisely as in the case of the pilot balloon. The observations of course may be either visual or photographic; the latter, if well done, generally being the better since it affords opportunity for

detailed study and independent measurements on many different points.

4. The angular altitude of a kite and the length of wire out, at the time it enters a cloud base, also furnish a fair means of computing the desired height.

5. The exact time of disappearance of a kite up into a cloud may be noted, and the height of the kite at that instant, and hence also of the cloud, determined by subsequent examination of the temperature and pressure records on the kite instruments.

6. The level of storm-clouds, or low clouds at the time of strong winds, and of ordinary cumuli, can be tolerably closely computed from the current values of the temperature and humidity.

The above are by no means all the possible ways of measureing the heights of clouds, but they are the more accurate, and the ones most commonly practised.

WHY THE BASE OF A GIVEN CLOUD, OR CLOUD SYSTEM, HAS EVERYWHERE NEARLY THE SAME HEIGHT.

One of the most interesting and significant things learned from cloud measurements is the fact that the base of any cloud sheet, that is, a particular sheet at a particular time, whether continuous or broken and scattered, is everywhere at about the same level. The reasons for this are very simple: (*a*) Since the temperature and humidity of the air at any given time are nearly the same at neighboring places over a considerable area, the height throughout such region is approximately constant at which rising air will have cooled to the dew-point and cloud begun to form. Hence the base levels of a series of detached cumulus clouds are about the same. (*b*) Since rising air ascends until, by expansion, it has cooled to the temperature of the then surrounding air, at which level it spreads out and drifts away with the general circulation, and as convection, whatever its cause, applies to air of all degrees of humidity, and occurs at different times and all manner of places, it follows that the atmosphere is always more or less stratified in respect to its water vapor. In general, therefore, clouds must also form in these layers. There may be, and often are, two or more cloud layers at the same time at different levels, but a cloud filling the whole depth of the atmosphere, or even a layer five or six miles thick, is not to be

expected, nor is any such layer of considerable extent often if ever formed.

LEVELS OF MAXIMUM CLOUDINESS.

Since several types of clouds occur at various elevations, and since no level, from the surface of the earth up to the highest cirrus, is free from condensation, it might seem that clouds are as likely to have one height as another throughout their possible range. However, it is certain that there are levels of maximum and minimum cloud frequency, even though it may not be as easy to prove some of them by direct observation owing to the prevalence of lower clouds. The more important levels of maximum cloudiness are:

Fog Level.—As every one knows, a fog, whatever its depth, from a mere gauzy veil to the deepest and densest layer, is a cloud on the earth. Obviously, therefore, the surface of the earth itself is a level of maximum cloudiness.

Cumulus Level.—Since evaporation tends all the time to saturate the atmosphere, and since humidity is held down by convectional condensation, and, further, since, over extensive areas, convection is roughly the same most of the time through an entire season, it follows that the ordinary rain cloud, and the common cumulus cloud, must have a roughly standard base level at a moderate elevation. This level, therefore, say 4000 feet above the surface, is also a level of maximum cloudiness.

Alto-cumulus Level.—The strong convection common to dry summer weather often produces small cumulus clouds at considerable heights—frequently two to two and one-half miles above the surface. Furthermore, during the average thunderstorm a great deal of humidity is urged up to roughly this same level, and there spread out into a wide layer by the swifter winds of that height. Subsequent convections in this layer often induce many small cumuli. For both reasons, therefore, this level, known as the alto-cumulus level, is likewise one of maximum frequency of cloud.

Cirro-stratus Level.—The topmost portions of the clouds in a cyclonic, or general, rain, are carried forward over very extensive areas by probably the swiftest winds of the entire atmosphere. Hence this level, roughly five miles above the surface, is also one of maximum cloud frequency, or at least of cloud observation.

Cirrus Level.—Rising masses of air can not ascend, for reasons well known, beyond the level of the highest cirrus clouds, that is, in middle latitudes, above an elevation of about six miles. Any air that reaches this level necessarily spreads out in an extensive sheet or layer in which, under favorable conditions, condensation occurs in the form of fine snow crystals. Hence this ultimate level of the ascending air, at which its horizontal spread is great, is also one of maximum cloud extent.

LEVELS OF MINIMUM CLOUDINESS.

If there are different levels of maximum cloudiness, it follows that between each two such adjacent levels there must be a level of minimum cloudiness. However, there is nothing of particular interest about any of these intermediate levels.

Why There Are no Clouds above the High Cirrus.—The region above the high cirrus also is one of minimum cloudiness. In fact clouds do not occur in that region at all, and the reason is as follows:

There clearly is some temperature (actually about 60 degrees Fahrenheit below zero) at which each portion of the high atmosphere must lose as much heat by radiation as it gains, and this is the lowest temperature to which the free air can cool. This temperature is reached, in middle latitudes, at about six to seven miles above sea-level. Hence this is the limit of vertical convection—for higher convection would mean lower temperatures—and the maximum height, therefore, to which water vapor is carried. Of course some water vapor reaches greater heights by the slow process of diffusion, but all of this region is subject to frequent temperature changes just as is the lower atmosphere, hence as soon as any appreciable amount of vapor diffuses to a higher level than that of the average cirrus it is frozen out in invisibly small amounts and the whole of the upper air thereby kept too dry for the formation of even the thinnest clouds.

RELATION OF CLOUD HEIGHTS TO SEASON.

Clouds generally are lower during winter than during summer. This is because the relative humidity is higher, or the atmosphere more nearly saturated, during the colder season than during the warmer. And this condition, in turn, is owing largely to the fact that vertical convection, which is the chief cause of rain and hence

the chief drying agency of the air, is most active during summer, when the surface of the earth is strongly heated.

RELATION OF CLOUD HEIGHTS TO LATITUDE.

Just as clouds generally are higher in summer and lower in winter, so, too, and for the same reason, clouds commonly are highest in equatorial regions and gradually descend with increase of latitude to their lowest level in polar regions.

RELATION OF TYPE OF CLOUD TO THE SEASON.

As just explained, vertical convection, which is due largely to surface heating, is much stronger during summer than during winter. Hence the cumulus or woolpack cloud, a product of local convection, is characteristic of warm summer days, while the low stratus or layer cloud is equally characteristic of the winter season.

RELATION OF TYPE OF CLOUD TO LATITUDE.

For the same reason that the prevailing type of cloud varies with the season, it also varies with latitude. That is, in tropical regions, where vertical convection is strong, the cumulus cloud is very common, whereas, in the high latitude regions, where convection is feeble, it is unusual. Here the prevailing cloud is of the stratus or layer type.

CLOUD THICKNESS.

The thickness of clouds varies from all but zero in the case of faint cirrus, and vanishing wisps and flecks of any other type, up to the ten miles or more of the deepest tropical cumulus. Habitually, however, the high cirrus, only a few hundred feet thick, is the thinnest of clouds; the cumulus, especially when the seat of a hail storm, is the thickest—often several miles deep. The common nimbus cloud, from which rain often falls all day, varies in thickness from, say, 500 feet, up to four or five miles. Its average thickness, however, appears to be, roughly, half a mile. All other types of clouds generally are intermediate in thickness between the cirrus and the nimbus, averaging, perhaps, 500 to 1500 feet.

CLOUD VELOCITY.

The direction and speed of travel of clouds can be determined in several ways, most of which involve triangulation of the kind

used by surveyors and geologists. In the great majority of cases the velocity of a cloud is that of the air in which it happens to be. In a few cases, however, the movement of the cloud is not that of its enveloping atmosphere. Thus the cloud that forms along the crest of a mountain is as stationary as a waterfall, and, like the waterfall, is continually renewed by fresh material. No matter how swift the current, the fall remains fixed, and however strong the wind over the mountain, cloud is formed in it as soon as it reaches a particular altitude, determined by the humidity and temperature, and evaporated as it is drifted beyond and to lower levels. The crest cloud, therefore, being always stationary, can not be used in measuring wind velocity. Neither can the riffle cloud, the lenticular cloud, nor the banner cloud, and for the same reason—all are stationary whatever the wind velocity.

Neither can the velocity of the wind be determined by the movement of the parallel rolls of the windrow or billow cloud. These clouds rest on the crests of air waves which are caused by the flow of one wind sheet over another. The velocity of these waves, and hence of the clouds that crest them, is intermediate between that of the two sheets, and therefore does not measure the actual velocity of either.

In the great majority of cases though, that is, with the above exceptions, clouds do move strictly with the enveloping air. Hence, though everywhere blowing, in the course of time, from all directions—boxing the compass, as the mariner says—in the tropics they are nearly always from easterly points, northeast to southeast, and in middle latitudes prevailingly from westerly regions.

Their average velocity, *when moving in their prevailing direction*, increases with height at approximately the same proportion that the density of the atmosphere decreases, that is, at such a rate that the product of the velocity (cloud or wind) by the density of the air is a constant.

VARIATION OF CLOUDINESS WITH LATITUDE.

As is well known, the amount of cloudiness varies greatly in different parts of the world. In some places it would be perfectly safe, following the example of the Yuma hotel, to advertise free meals for every day the sun does not shine; and equally safe in others to make a similar offer for every whole day that it does. Apart from such obvious causes of cloud variation as direction of

the wind, particularly onshore and offshore, elevation, temperature, *et cetera,* there is also a well-marked latitude effect. Thus, in the equatorial regions, where convection is most active, nearly 60 per cent., on the average, of the sky is clouded; around latitude 30 degrees, both north and south, or along the great belts of high pressure, and over the principal arid regions, the average cloudiness falls to the minimum value of 40 to 45 per cent.; while in the neighborhood of the polar regions it becomes 60 to 75 per cent. All these are only average values for the respective latitudes. The cloudiness of individual places covers a much wider variation.

CLOUD SPLENDORS.

Crepuscular Rays.—Everyone is familiar with the beautiful phenomenon of the "sun drawing water" (Fig. 36)—sunbeams, that, finding their way through rifts in the clouds, are rendered luminous by the dust in their paths. Many people seem to consider this splendor an excellent weather sign: Some insisting that it foretells rain, while others as strongly claim it indicates continued fair. As a matter of fact, it has no significance either way, hence its excellence as a bone of contention.

When there are a number of such rifts the beams of light seem to radiate from the sun like spokes from the hub of a great wheel, or like ribs from the pivot of a giant fan. However, they are practically parallel, for the sun, from which they all come, is 93,000,000 miles away. The seeming divergence is only a perspective illusion, the same as that which makes any long, straight, parallel lines, such, for instance, as the rails on a straight, level track of railway, appear to come closer and closer together with increase of distance.

Lightning.—Few things in all nature so widely range our sensibilities, from thrills of joy over the exquisitely beautiful to abject terror in the face of imminent death, as does the lightning's flash from the heart of the thunder cloud.

The story of this wonder meteor—how Franklin showed it to be a form of electric discharge; how, as explained by Simpson, charge after charge is obtained within the cloud; what curious freaks it plays and marvellous things it does—is delightful in every detail, but far too long to include here, for, after all, lightning, whatever its interest and importance, is only a cloud incident.

When the storm is close by it is easy to see that lightning con-

sists of one or more sinuous (not zigzag, as the artist paints it) lines or streaks of vivid white or pink. Often there is one main

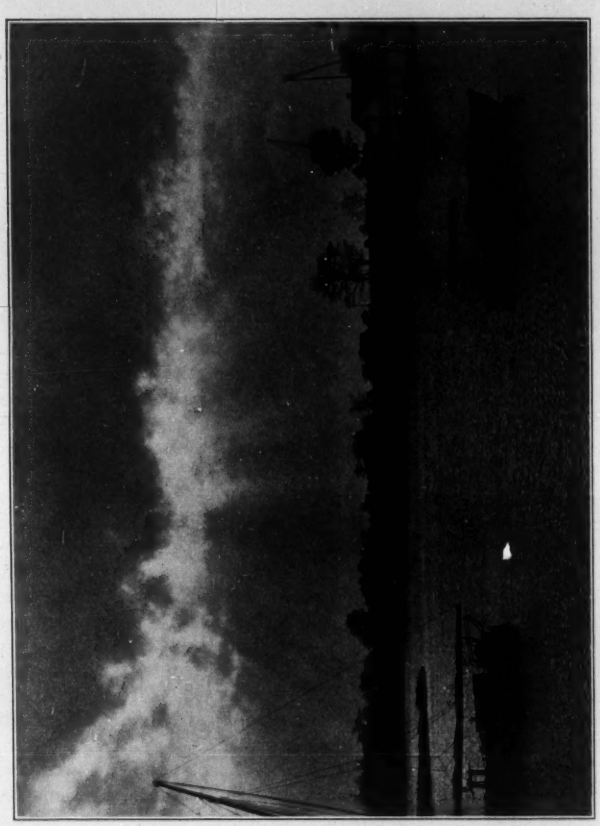


FIG. 36. Crepuscular rays, seen on the Potomac River. (P. E. Budlong, photo.)

trunk with a number of branches, all occurring at the same instant, while at other times there are two or more simultaneous, disconnected streaks. Frequently the discharge, instead of being all

at once, continues flickering; and, on rare occasions, even stationary, like a glowing wire, during a whole second, or more.

The autobiography of a typical flash of lightning is jointly given by Fig. 117, *Physics of the Air,* obtained with a stationary camera, and Fig. 118, *Physics of the Air,* taken at the same time with a rotating camera, and showing a number of separate discharges which together constituted the flickering whole, each faithfully following the path ionized by the initial member of the series.

The Rainbow.—Unlike the phenomenon of lightning the rainbow is all beauty and splendor, with nothing whatever of the appalling—save alone to the physicist who undertakes to explain fully and clearly its every detail, a most difficult task. Perhaps this assertion may seem strange when so many text-books, even some that are quite elementary, profess to explain the rainbow so simply that a child can understand it, but in this particular nearly all these books have the same fault: They "explain" beautifully that which does not occur and leave unexplained that which does.

The ordinary rainbow seen in a sheet of water drops—rain, spray, fog—is a group of circular or nearly circular arcs of colors whose common centre is on the extension, in the direction of the observer's shadow, of the straight line connecting his eye with the luminous source, which, as everyone knows, is nearly always the sun, but not quite, for once in a while the moon too produces a very pretty bow.

Frequently there are two entirely different bows. The inner one, known as the *primary,* with red outer border of about 42 degrees radius, and blue to violet inner border, is much brighter than the larger, or *secondary* bow, of about 50 degrees inner radius, and whose colors occur in the reverse order of those of the primary bow. In addition to these two conspicuous bows one can often see from one to, rarely, half a dozen parallel, colored arcs just inside the primary bow, and a smaller number just outside the secondary bow. These are known as the *supernumerary* bows. Most of these phenomena are shown in Fig. 37, copied, by kind permission, from a remarkably fine picture taken by Mr. G. A. Clarke, of Aberdeen, Scotland.

A careful observer will soon see that there is less light (that the clouds look darker) between the two bows than outside the secondary or within the primary; that the colors seen are not

always the same; that the band of any given color varies in angular width, even, occasionally, from place to place in the same bow;

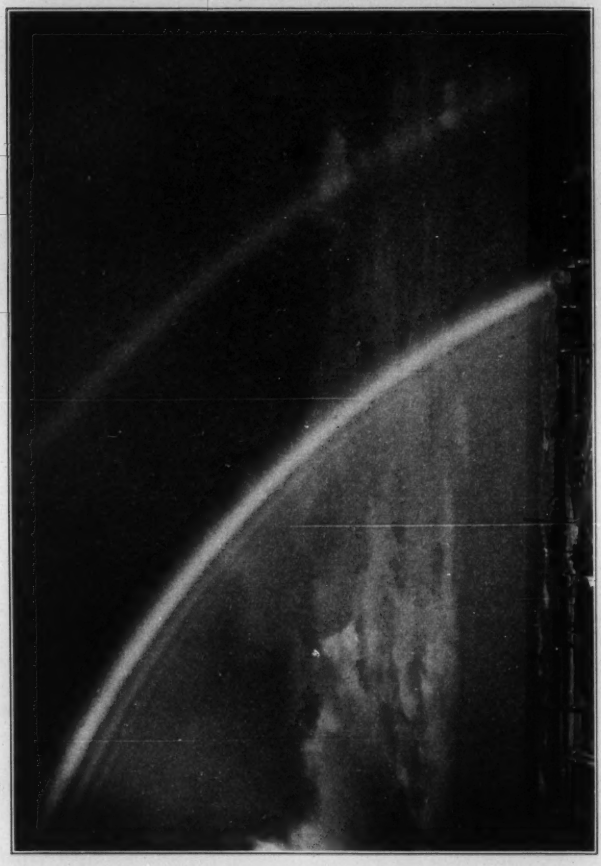


FIG. 37.

Rainbow, primary, secondary and supernumeraries; seen at Aberdeen, Scotland. (G. A. Clarke, photo.)

and that the purity of the colors varies from time to time. As one would naturally suspect, all, or nearly all, these differences

depend on the size of the droplets. The greatest contrast, perhaps, is between the brilliant rainbow of the retreating shower and that ill-defined, faintly tinged bow one sometimes sees on a sheet of fog.

The Halo.—As must be obvious to anyone, the cirrus and other very cold clouds nearly always consist of ice crystals. These reflect some of the light that falls upon them; and some of it they transmit, bent, or refracted, as we say, out of its course and split up into all its color, but always with the red nearest to the source of light. Both the refracted and the reflected light produce various bright patterns properly known as halos.

By refraction we get: The very common ring of 22 degrees radius about the sun or moon (Fig. 9); the less frequent ring of 46 degrees radius; the occasional brilliantly colored arc that has its centre directly overhead and its convex side next the sun; and, rarely, numerous other splotches and arcs, all more or less distinctly colored, and things of beauty and interest.

By reflection, on the other hand, we get only white or colorless figures; chiefly, the parhelic circle, Fig. 9, that passes through the sun and is parallel to the horizon; and a pillar of light that rises straight up through the sun, much as would its reflection in rippled water if stood on end.

The Corona.—Thin clouds of water droplets also produce beautiful colored rings about the sun and moon, but usually much smaller than the circles formed by refraction through snow crystals, and with their colors in reverse order, that is, with the red farthest from the source of light, instead of nearest to it. These rings, known as coronas, are owing to what the physicist calls diffraction, or, in this case, the bending of the light around the droplets into their shadows. They are most frequently seen about the moon, but may be seen even more brilliantly, occasionally in a widening series of two or three repetitions of the colors, about the sun, if one will use dark glasses to cut down the glare.

Fig. 38, from a drawing by Mr. G. A. Clarke, of Aberdeen, Scotland, shows a magnificent corona and also contains other phenomena observed by him at that place on June 13, 1921. These were: (*a*) The slightly veiled image of the sun; (*b*) an aureole of faintly colored light close to the sun; (*c*) a triple corona in which the radii of the red or outer borders of the three rings were

about 6 degrees, 10 degrees, and 16 degrees, respectively; (*d*) iridescence (see below) merged with and extending beyond a portion of the outer coronal ring; (*e*) portions of a fine halo of 22 degrees radius, produced by a background of thin cirro-stratus.

Cloud Iridescence.—Unquestionably the most beautiful thing in all the heavens is a magnificent display of iridescent clouds—

FIG. 38.

Corona, triple, and 22° halo, drawn by G. A. Clarke, Aberdeen, Scotland.

numerous splotches among the cirro-cumuli, or other high type, and borders of thin lenticular alto-strati and alto-cumuli, of gorgeous opalescent rose pinks, emerald greens, and other colors, randomly mixed and covering a large part of the sky 15 to 30 degrees from the sun.

It can be fully explained (being only fragments of giant coronas due to unusually small droplets), but only in the language of the physicist and symbols of the mathematician. Its beauty, however, can be enjoyed by all, and whoever looks at the heavens for anything should watch most frequently and carefully for the glorious apparition of the iridescent cloud.

CLOUDS AS WEATHER SIGNS.

Since the height, extent and shape of clouds depend upon the humidity, temperature and motion of the atmosphere it is obvious that they often may furnish helpful hints of the coming weather. Thus, thin cirrus clouds, when not increasing in extent nor growing denser, indicate fair weather for at least twenty-four hours; and the same is true of the alto-cumuli. In general

"The higher the clouds, the finer the weather."

On the other hand, when the cirrus grows denser, and when the sky is covered with cirro-cumuli, rain within twenty-four hours is likely.

"Mackerel scales and mares' tails
Make lofty ships carry low sails."

Also, when large cumuli develop in the forenoon, there probably will be local thundershowers in the afternoon.

"In the morning mountains,
In the evening fountains."

Again, when two or more layers of cloud are moving in different directions, foul weather is almost certain to occur very soon. In short, if one may coin a "proverb,"

Whene'er the clouds do weave
'Twill storm before they leave.

Clouds of the lower and intermediate levels from north to west usually imply fair weather for a day or two; clouds from east to south generally mean rain within twenty-four hours. (This is for most of the temperate regions of the northern hemisphere; for the southern hemisphere, write north for south, and south for north.)

"When the carry [current of clouds] goes west,
Gude weather is past;
When the carry goes east
Gude weather comes nest."

Fog clearing up early means a fair day; fog persisting implies that there probably will be rain later in the day, or during the coming night. As the proverb puts it:

"Mists dispersing on the plain,
Scatter away the clouds and rain;
But when they hang on the mountain tops
They'll soon descend in copious drops."

BIBLIOGRAPHY

Anyone especially interested in clouds will find several, if not all, of the following worth reading:

Ley, W. Clement, "Cloudland," London, 1894, xiv, 208 pp.; 8vo. (A study on the structure and characters of the clouds.)

Clayton, H. Helm, "Observations Made at the Blue Hill Meterological Observatory—Discussions of the Cloud Observations," Cambridge, 1896, 269–500 pp.; 4to. *(Annals of the Astronomical Observatory of Harvard College,* v. 30, pt. 4.)

Clayden, Arthur W., "Cloud Studies," London, 1905, xiii, 184 pp.; 8vo.

Vincent, J., "Atlas des Nuages," Bruxelles, 1907, 29 pp.; folio. *(Annales de l'Observatoire Royale de Belgique, Nouvelle Série. Annales Météorologiques.)*

Loisel, Julien, "Atlas Photographique des Nuages," 2 ed., Paris, 1912, folio. (20 Cloud Photographs.)

Neuhaus, E., "Die Wolken," Zurich, 1914, 48 pp.; 30 cloud photographs, 4to. (Use of clouds in local forecasting.)

Taffara, L., "Le Nubi," Rome, 1917, 67 pp.; 4to. (50 good cloud photographs; details of cloud observing and photographing.)

Clarke, G. A., "Clouds," London, 1920, xvi, 136 pp., 12mo. (Forms, causes, distribution, and weather significance; many excellent illustrations.)

Echoes from the Past.—The Franklin Institute has recently received by gift a copy of a volume of Berzelius' "Lehrbuch der Chemie," dated 1836. In discussing the use and value of the chemical symbols (which were introduced by Berzelius) reference is made to the fact that a French work on mineralogy lately published had used symbols derived from the French names of the common elements instead of from the Latin names, as Berzelius did in order to make them international. As a protest against this "national vanity," the author quotes from a speech Davy made, as president of the Royal Society, in presenting the Coplay medal to Arago, for discoveries in magnetism. Davy said "Science, like the nature to which it belongs, is neither limited by time nor space; it belongs to the world and is of no country and of no age."

In connection with this statement is a collection of replies to some objections that have been made to the symbols. They were declared obscure, misleading and purposeless. It was said that they are displeasing to mathematicians, inasmuch as the exponent attached to the symbols has a higher value in mathematical formulæ than in the chemical, and the mathematician should have the right of way in such matters. It also objected that in Greek and Russian P is read as R. These objections were mostly ignored, but early in the application of symbols the objection in regard to the significance of the exponents was met by writing them as inferiors, a system which has been universally adopted except by French chemists and it is to be hoped that they will fall in line soon. H. L.

ELECTRIC RAILWAY DISTURBANCES AND THE DETECTION OF PASSING ELECTRIC TRAINS BY MEANS OF A GALVANOMETER.*

BY

E. S. BIELER, M.Sc.

Exhibition of 1851, Scholar of McGill University, Montreal.

DURING a series of experiments carried out in the Macdonald Physics Building, McGill University, on the currents induced in a conductor by the passage of a sphere of magnetic material over it,[1] considerable trouble was at first experienced due to disturbances apparently connected with the passage of electric cars in the neighborhood.

The apparatus used consisted of a coil of 200 turns of copper wire wound on a square frame of 125 cm. side, and connected to a sensitive reflecting galvanometer of the moving coil type. The galvanometer deflections were registered photographically on a roll of bromide paper actuated by clock-work. With a total external resistance of 224 ohms, equal to the critical damping resistance of the galvanometer, a sensitivity of 1.56 mm. per microvolt was obtained.

When the coil was placed with its plane horizontal, a continual motion of the galvanometer spot was observed. This attained a maximum amplitude at the rush hour on the street car system, and ceased almost completely about 2 A. M., Standard Time, when the street car service is practically suspended (See Fig. 1). On the whole, the disturbances agreed well with the supposition that they were due to currents in some way connected with the operation of the street cars in the neighborhood. These disturbances could be almost completely balanced out by placing in series with the coil a large loop of wire of three turns enclosing a total area equal to the combined area of the turns of the coil. The fact that this was possible indicates that the source of the disturbance must be at a distance from the apparatus, fairly large compared with the linear dimensions of the loop, and shows defi-

* Communicated by Dr. A. S. Eve, C.B.E., F.R.S., Associate Editor, Corresponding Member.

[1] E. S. Bieler, *Proc. Roy. Soc.*, vol. c, p. 50 (1921).

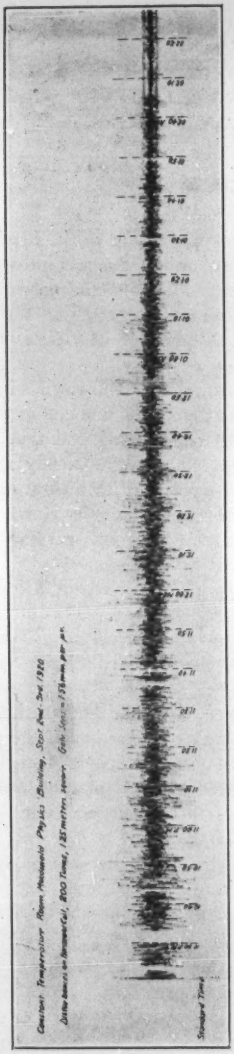


FIG. 1.

nitely that it cannot be either inside the building or in its immediate neighborhood.

When the coil was placed in a vertical plane, on the other hand, there was practically no disturbance, and it was not necessary to use any balancing loop. This was rather unexpected, as the circuit composed of the trolley wire and the rails ought to have an appreciable mutual induction with any circuit in a vertical plane in its neighborhood.

At the time when these observations were made Doctor Eve had been supervising some experiments to determine whether the passage of electric trains through the C.N.R. tunnel under Mount Royal produced any mechanical disturbance in the university buildings straight above it. He suggested that the galvanometer and coil should be set up in the basement of the library, 60 ft. directly above the axis of the tunnel, in order to detect any electrical disturbance.

The coil was accordingly placed with its plane in the axis of the tunnel, and the deflections of the galvanometer registered in the usual manner. In addition to a continual disturbance of small amplitude, large deflections were obtained, which coincided exactly with the times of trains. One of the records obtained is shown in Fig. 2. The times at which trains were heard to pass

FIG. 2.

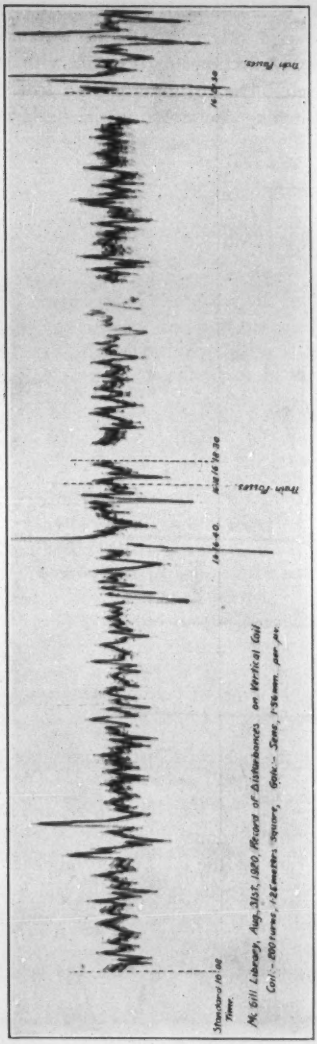
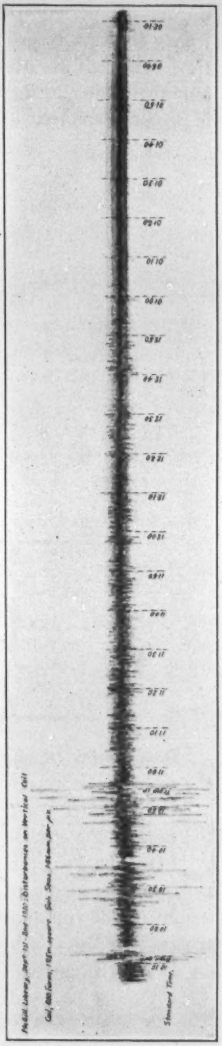
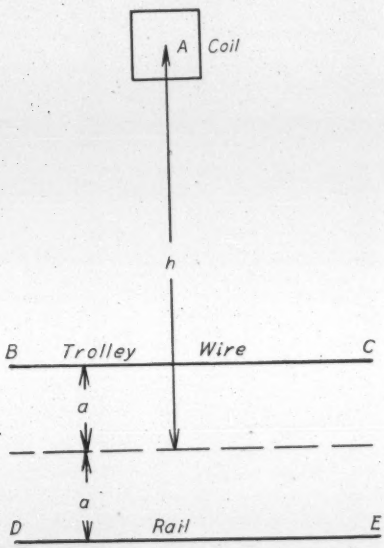

Standard Time
McGill Laboratory, Aug. 31st, 1920. Record of Disturbances on Vertical Coil
Coil:- 800 turns, 124 metres square, Gain:- Zero, 1·38 mm. per mm.
Train Passes.
Train Passes.

FIG. 3.


McGill Laboratory, March 1st, 1921. Disturbances on Vertical Coil
Coil 800 turns, 140m square. Gain Zero. 1·48 mm per mm
Train in
Standard Time

during the period correspond with the two large disturbances. Fig. 3 shows a record taken over a longer period with a reduced time scale. Two of the large deflections correspond with the only two trains during the period. The disturbance at 10.30 P. M. is probably connected with switching operations in the station.

FIG. 4.



It will now be shown that the observed disturbances are of the order to be expected.

In Fig. 4, let A represent the coil, BC the trolley wire, and DE the rails of the electric railway in the tunnel.

Let S be the area of one turn of the coil, n the number of turns, $2a$ the height of the trolley wire above the rails, and h the height of the coil above a line midway between the rails and the trolley wire.

If i is the current in the trolley wire at any time, the field at

A due to i and the return current through the rails is equal to

$$\frac{2i}{10(h-a)} - \frac{2i}{10(h+a)} = \frac{4ai}{10(h^2-a^2)}$$

If N is the total number of interlinkages between the tubes of induction due to i and the turns of the coil, the emf induced in the coil when the current changes is given by

$$E = -\frac{dN}{dt} \times 10^{-8} \text{ volts}$$

$$= -\frac{4naS}{h^2-a^2} \frac{di}{dt} \times 10^{-9} \text{ volts}$$

Now, the deflections obtained are of the order of 5 cm. and E is therefore of the order of 30 microvolts. Also, the side of coil is 125 cm., and the approximate values of h and a are 2000 cm. and 200 cm. respectively.

Substituting these values in the above equation, and solving for $\frac{di}{dt}$, we obtain,

$$\frac{di}{dt} = 50 \text{ amperes per second,}$$

approximately.

This is of the right order for the rate of change of current taken by an electric locomotive when starting or stopping.

A similar calculation can be made in the case of the street car disturbances mentioned above.

If $2a$ is as before the height of the trolley wire above the rails, and d the horizontal distance between the coil and the line, it is easily shown that the emf produced in the coil when set in a vertical plane parallel to the line is given by

$$E = -\frac{4naS}{d^2+a^2} \frac{di}{dt} \times 10^{-9} \text{ volts}$$

The distance from the nearest street car line was about 300 yards. Even if we assume for E a value as large as 50 amperes per second, the value of E obtained is only 0.14 microvolt. This would give a deflection of 0.2 mm. approximately.

It is easily seen that current variations in a circuit composed of the trolley wire and the rails of a street car line can induce no emf in a horizontal coil at their own level.

We must conclude therefore that the disturbances mentioned in the beginning of this paper cannot be caused directly by the

currents in the trolley wires and rails, but must be due to large currents flowing at no great distance from the building, approximately at the level of the laboratory where the experiments were conducted. This may be due to a power line connecting the street-railway power house to a distant part of the system, or to a return current along some metal pipe-line.

A current variation of 50 amperes per second in a single conductor 200 metres from the building or a smaller current at a proportionally smaller distance would give deflections of the order observed.

The departure of the writer for England made it impossible for him to pursue these experiments further, and to locate the exact cause of these disturbances. The results obtained are communicated with the hope that they will be of some use, in view of the ever increasing number of electric traction lines, and the trouble they must necessarily cause to all who attempt delicate electrical measurements in their neighborhood.

The author's thanks are due to Dr. A. S. Eve for his kind interest in these experiments.

CAVENDISH LABORATORY,
CAMBRIDGE, ENGLAND,
December, 1921.

New Method of Hydrogenation.—GRANICHSTÄDTEN and SITTIG describe, in *Giornale di Chimica,* the use of a nickel-magnesium silicate as a catalyst of high power in hydrogenation, oils acquiring an unusual degree of whiteness at not above 40° C. With most methods now in use dark oils must be previously bleached if desired to be of good color, but with the new process this bleaching is not required. The catalyst is prepared by precipitation so as to secure as uniform a product as possible. The procedure promises to be widely used and is to be covered by patents.—*Chem. News.*

H. L.

Composition of a South American Copper Axe Head.—A. K. GOAD and E. K. RIDEAL (*Analyst,* 1921, xlvi, 490) have analyzed an axe head which had belonged to an Inca Indian. It contained 96.44 per cent. copper, 3.44 per cent. zinc, 0.09 per cent. iron, and traces of silica; tin, lead, and nickel were absent. These results indicate that the axe head was composed of brass and not of copper, and that the aborigines had a knowledge of brass.

J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

AN INVESTIGATION OF OXYACETYLENE WELDING AND CUTTING BLOWPIPES WITH SPECIAL REFERENCE TO THEIR ECONOMY IN OPERATION, SAFETY, AND DESIGN.[1]

By Robert S. Johnston.

[ABSTRACT.]

At the request of the Standardization Section, Purchase Branch, Purchase, Storage, and Traffic Division of the War Department, the Bureau conducted an investigation of the operation, efficiency and safety of oxyacetylene welding and cutting blowpipes. Apparatus from fourteen different manufacturers were submitted to test. The tests were decided upon after a careful survey had been made of the technical literature on the subject and a thorough study made of the various operations in which these blowpipes are used. Suggestions for methods of tests were also secured from the manufacturers.

All blowpipes were submitted to a standard series of tests which were developed with the idea of minimizing the personal equation of the operator and securing data that was representative only of the blowpipe itself. In order to accomplish this result a rather elaborate testing equipment consisting of a weighing system, a gage-board equipment, welding table, cutting table, and safety and flashback testing apparatus was designed and used throughout the investigation.

The weighing system was used to determine the amount of gas consumed in any blowpipe operation, the process consisting in determining the loss of weight of banked tanks of oxygen and acetylene. In order to transfer the loss of weight into cubic feet of oxygen and acetylene consumed, special studies of the density of oxygen and acetylene were made. The gage-board system comprised a flow meter designed and calibrated for this investigation which was used to furnish a check upon the quantity of gas consumed in the welding and cutting operations and also to secure

* Communicated by the Director.

[1] Technologic Paper, No. 200.

data that would show the fluctuation of gas volumes used at different periods of time during a test.

Special care was taken to furnish the gas delivered to the blowpipes at the pressure specified by the manufacturers. To accomplish this, special compound manometers were designed and used throughout the investigation, Bourdon tube gages being only used as check apparatus. Besides observational data of the gas volume being consumed as indicated by flow-meter differential manometers and the pressures delivered to the blowpipes, autographic recording gages were also installed to secure graphical representation of the pressure fluctuations.

All welding blowpipes were submitted to welding tests on ½ in. and ¾ in. metal. The operation of the blowpipe, however, was necessarily performed by experienced operators. For the cutting tests the blowpipes were mechanically guided and controlled so that practically all personal equation of the operator was eliminated. During the cutting tests the blowpipes were operated at the maximum speed at which they would cut metal of specified thickness. One-half in., 2 in., 6 in., and 10 in. metal were used in the cutting tests.

A further series of tests was made to determine the freedom from flashback and safety of operation of the various welding blowpipes.

The results of the initial series of tests carried out on the welding blowpipes indicated that there were some phenomena in connection with the operation of a welding blowpipe that were not understood. A very thorough study of the design of the various welding blowpipes was therefore made, and certain conclusions relative to the cause of the inconsistencies in action noticed arrived at. A supplementary series of tests was then carried on to prove the correctness of these conclusions. From this secondary investigation it is shown that the proper principles upon which the design of oxyacetylene welding blowpipes should be based were probably not fully realized. The results of this entire investigation may be summarized as follows:

For the Cutting Blowpipes.

1. There is to-day no generally accepted theory for proportioning, for the cutting of metal of various thicknesses, the volume

and velocity of the issuing cutting jet, with the result that none of the apparatus submitted to test proved economical for all thicknesses.

2. There is for any thickness of metal cut a limiting velocity of exit of the cutting jet at which complete utilization of the oxygen takes place, and there is a limiting value for the amount of oxygen required to produce a cut.

3. An increase in acetylene consumption, in oxygen consumption, or in the velocity of exit of the cutting jet beyond the limiting value does not produce increased efficiency in commensurate ratio.

4. A large majority of the blowpipes tested were equipped with excessive preheating flames for the thickness of metal the tip is specified for, and such excessive sized flames are disadvantageous both from the standpoint of economy of operation and quality of work performed.

5. Considerable improvement in economy of operation seems possible in cutting material of 2 in. thickness; possibly this condition may be found to exist for metal of other thicknesses than those used in the tests.

6. The maximum thickness of metal that may be economically cut with an oxyacetylene blowpipe of standard design when neither the material nor the oxygen is preheated and the cutting is done only from one direction is about 12 in.

7. Cutting blowpipes, due to their incorrect design, are subject to the same flashback troubles found in the welding blowpipes.

For the Welding Blowpipes.

1. The blowpipes most subject to the so-called phenomena of "flashback" are those in which the oxygen is delivered at a pressure in excess of that at which the acetylene is delivered.

2. All the blowpipes tested, including those in which the acetylene is delivered at an excess pressure as well as the so-called equal or balanced pressure blowpipes are subject to flashback phenomena on account of inherent defects in their design.

3. The cause of the development of the conditions producing flashback is the setting up, within the blowpipe tip and head, of a back pressure which retards or chokes off the flow of one of the gases.

4. This lack pressure is the result of confining or restricting the volume flow of the issuing gases at the tip end.

5. Any cause tending to restrict the flow of the gases sets up a back pressure which immediately causes a change in the amount of each gas delivered to the mixing chamber.

6. A fluctuating gas-volume ratio, due to restriction of volume flow from whatever cause, prevents a blowpipe from maintaining constantly and at all times during operation the desired "neutral flame."

7. A blowpipe that can not maintain under all operating conditions a neutral flame can not logically be expected to produce sound welds.

8. All the blowpipes tested during this investigation either through improper gas pressures or improper interior design, or both, are incapable of maintaining a neutral flame (constant volume gas ratio) under all conditions of restricted gas flow and are therefore incapable of producing sound welds where there is any liability of the gaseous products of combustion being momentarily confined, such as occurs in practically all welding operations.

9. The ability of a blowpipe to consume an equal volume ratio of gases when burning freely and undisturbed in air is no criterion that it is capable of producing sound welds, that is, that it is not subject to detrimental fluctuations in gas ratio during a welding operation and therefore is capable of maintaining a neutral flame under all operating conditions.

10. Whether a blowpipe of present design will consume equal volume ratio of gases when burning freely and undisturbed in air depends on how nearly correct the operator sets the so-called "neutral flame," and experience indicates that the average operator checks the acetylene gas flow too much and actually develops an oxidizing rather than a neutral flame.

11. The question of the possible limiting strength and ductility or the efficiency of welds made by the oxyacetylene welding blowpipe must await the development of a more satisfactory instrument, and, having such an instrument, there is reason to believe that a weld of clean, sound metal can be made with assurance during any welding operation and that such welds will or can be made to possess the proper physical properties.

THE RADIO DIRECTION FINDER AND ITS APPLICATION TO NAVIGATION.[1]

By Frederick A. Kolster and Francis W. Dunmore.

[ABSTRACT.]

THE radio direction finder is a device for determining in a simple manner the direction of a radio transmitting station with reference to the point at which the direction finder is located. The direction finder has a number of very practical applications, of which one of the most important is its use as an aid to navigation.

Sound and visual signaling devices have been employed for many years as aids to navigation. Lighthouses and lightships with their characteristic light flashes and sound signals are established and maintained along the coasts and at harbor entrances in order that shipping may be carried on with maximum safety. During fog or thick weather, however, the sound and visual signaling devices do not give reliable service.

The radio direction finder is not affected by fog, and has the further advantage that it will operate over much greater distances than sound and visual signaling devices.

A common type of direction finder, as developed by the Bureau of Standards for installation on shipboard, and as at present used, consists of a coil of ten turns of copper wire wound on a frame four feet square which is mounted so that it may be rotated about a vertical axis. Associated with the coil is suitable radio receiving apparatus and also a device for reading the radio bearing.

As the coil is revolved, the intensity of this signal which is being received from the station whose location is to be determined, diminishes until a minimum is reached, which occurs when the plane of the coil comes to a position at right angles to the line of direction to the radio transmitting station. At this point of minimum signal, the radio bearing is read on a suitable scale, which may be either a fixed scale, or the card of a magnetic compass. A radio transmitting station intended primarily for direction finding work is often called a "radio beacon."

This paper deals briefly with the principles of the operation of the direction finder, but is primarily concerned with practical development which has made possible a device sufficiently simple

[1] Scientific Papers, No. 428.

and accurate for use as an aid to navigation, and with practical applications which have been made.

The developments have included a study of the distortion effects which may result from the presence of adjacent objects, such as the mass of a ship, and methods of eliminating errors which such distortions may cause in observed radio bearings. A particularly careful study has been made of distortion effects on shipboard and methods for correcting these effects by calibration.

Practical methods have been developed for simplifying the operation of the direction finder. The direction finder is essentially a nautical instrument and should be installed on shipboard where it may be used directly by the navigator in taking bearings on radio signal stations established on shore or on light vessels. This can be done with the simplified form. Bearings may thus be taken rapidly, at any time, and as often as desired.

The system here described should be carefully distinguished from another system of determining position by radio which is now in use, in which the ship transmits signals to radio compass stations on shore, which report to the ship its position, by radio. Delays and errors are inherent in the system with the radio compass on shore, and even under the most favorable conditions the time consumed in making a request for bearings, taking bearings, and getting the information in the navigator's hands, is too great.

The radio direction finder as described involves a number of unique features. It is designed to be installed over the ship's binnacle carrying the magnetic compass, and an additional scale is attached to the top of the binnacle and marked with the corrections obtained by calibrating the radio direction finder. By these means the radio bearings are obtained in a simple and direct manner. The electrical features have been made such that the only operations necessary when taking a radio bearing are one adjustment in the radio receiving set and the rotating of the direction finder coil.

The paper contains numerous photographs of a radio direction finder of the above-mentioned type, as installed in the pilot house of a lighthouse tender. Actual courses are shown which were run by means of radio bearings taken by the ship's navigator. The bearings were taken on the three radio beacons which have been established by the Bureau of Lighthouses at the approaches to New York harbor on Ambrose and Fire Island Lightvessels, and at Sea

Girt Lighthouse, Sea Girt, New Jersey. These automatic radio beacons are described and illustrated in the paper.

In these tests, positions were determined by cross bearings on the three radio beacons, and courses were set for one of the light vessel beacons by taking a radio bearing directly on the beacon.

The work described in this paper was done in close coöperation with the Bureau of Lighthouses, particularly the Lighthouse Depot at Tompkinsville, New York.

The system of radio direction finding described has already proved to be a very practical and an extremely effective aid to navigation, particularly in time of fog or thick weather.

The paper points out the importance of establishing as soon as possible radio beacons at the other important light stations on the Atlantic and Pacific coasts and the installation of radio compass equipment on shipboard.

SOME EFFECTS OF THE DISTRIBUTED CAPACITY BETWEEN INDUCTANCE COILS AND THE GROUND.[3]

By Gregory Breit.

[ABSTRACT.]

IT is well known that the effective capacity of two condensers connected in series is $\frac{C_1 C_2}{C_1+C_2}$ if C_1, C_2 are the capacities of the two condensers.

This fact would make it plausible to think that if two condensers of capacities of C_1, C_2 are connected in series with an inductance and if one or the other is adjusted until resonance of the system with an emf of given frequency is obtained, then the quantity $\frac{C_1 C_2}{C_1+C_2}$ must stay constant for different adjustments of C_1 and C_2.

In practice, however, accurate condensers are provided with shields and for this reason they must be used with the shielded terminals grounded.

If the shielded terminals of the two condensers are connected together and are grounded while the unshielded terminals are connected to the coil, it is found that the simple relation suggested above does not hold.

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[3] Scientific Papers, No. 427.

It is shown that for resonance the values of C_1 and C_2 must satisfy a relation of the form

$$\frac{A}{C_1}+\frac{B}{C_2}+\frac{D}{C_1 C_2}+F=0$$

so that if the two coil terminals are symmetrical

$$A+\frac{D}{C_1+C_2}+F\frac{C_1C_2}{C_1+C_2}=0$$

is the relation for resonance at a given frequency. This is a linear relation between $\frac{C_1C_2}{C_1+C_2}$ and $\frac{1}{C_1+C_2}$ and experimentally it is found that such a relation holds.

THERMAL EXPANSION OF NICKEL, MONEL METAL, STELLITE, STAINLESS STEEL, AND ALUMINUM.[4]

By Wilmer H. Souder and Peter Hidnert.

[ABSTRACT.]

THE increasing use of commercial nickel in spark plugs, of monel metal for high pressure steam valves, stems, seats, etc., of stellite for surgical and household uses, of stainless steel for numerous purposes such as aeroplane and automobile engine valves, pump rods and marine fittings and of aluminum, or its alloys, almost universally where lightness is necessary, has created a demand for data on the thermal expansion of these materials.

This paper includes original data on the thermal expansion of ten samples of commercial nickel, ten samples of monel metal, five samples of stellite, two samples of stainless steel and two samples of exceptionally pure aluminum, in addition to the results obtained by previous observers on the expansion of nickel and aluminum. All these materials except stainless steel were examined from room temperature to about 600° C. The samples of stainless steel were heated from room temperature to 900° C. The apparatus used was essentially the same as that described in Scientific Paper of the Bureau of Standards No. 352

Commercial Nickel (10 samples, 94 to 99 per cent. Ni.).—Five samples were hot rolled, and the remaining five samples of corresponding compositions were hot rolled and annealed. In most of the expansion curves of these samples of commercial nickel, a

[4] Scientific Papers, No. 426.

slight irregularity was perceptible in the region near 350° C., but there was no marked change or anomalous expansion such as was observed by the previous investigators in the case of pure nickel. Annealing of the hot rolled samples of nickel, usually caused a slight increase in the values of the coefficients of expansion.

Monel Metal (10 samples, 60 to 69 per cent. Ni.).—Two samples were cast, and three were hot rolled. The remaining five specimens of corresponding compositions and treatments, received additional heat treatment, that is, they were annealed. The expansion curves of monel metal were found to be fairly regular. The average coefficients of expansion of the various samples for the range from 25° to 300° C. are all practically equal. For the temperature range from 25° to 600° C. the average coefficients of the cast samples are greater than those of the hot-rolled alloys.

Stellite (5 samples of various grades).—The expansion curves show irregularities in the region between 300° and 500° C. The stellite containing 10 per cent. tungsten has the smallest coefficients of expansion of all the samples investigated. The hammered stellite has smaller coefficients than the unhammered sample of corresponding composition, which indicates that hammering may lower the value of the coefficients of expansion.

Stainless Steel (2 samples).—The expansion curves including the critical regions of an annealed and a hardened sample of stainless steel were determined. On heating, both samples indicated critical regions which extended from approximately 825° to approximately 855° C. The transformation point on cooling occurred at approximately 800° C. Up to the transformation regions, the heating and cooling curves of the annealed samples are fairly regular. In the case of the hardened stainless steel, the curve is irregular between 200° and 400° C., where the strains produced in hardening were released. Above 400°, this sample behaved like the annealed specimen. The coefficients of expansion of these stainless steels are less than the coefficients of ordinary iron or steel.

Aluminum (2 samples, 99.74 per cent.).—The thermal expansion of the two samples of cast aluminum investigated between room temperature and 600° C. may be represented by the following empirical equation:

$$L_t = L_0 [1 + (21.90t + 0.0120t^2)\ 10^{-6}]$$

CHARACTERISTIC SOFT X-RAYS FROM ARCS IN GASES AND VAPORS.[1]

By F. L. Mohler and Paul D. Foote.

[ABSTRACT.]

IF an electron current is maintained by a potential V between a hot cathode and anode in a vapor at low pressure, then as V is increased successive changes occur in the spectrum excited by electron impact. The highest frequency ν of each additional group of lines is related to the least potential required to excite the group by the quantum equation $Ve = h\nu$ or $V \text{ (in volts)} = \frac{12345}{\lambda \text{ (in } A)}$.

The authors have studied the stages in the discharge by measuring the photo-electric effect of the radiation on two other electrodes entirely shielded from ions produced in the arc. This photo-electric current plotted as a function of the exciting voltage shows nearly a linear relation with changes of slope at critical potentials. In this manner potentials have been found which are determined by the limiting frequency of the softest X-ray series of a number of elements.

The table gives the observed potentials, and the corresponding wave-lengths for these X-rays. Carbon was studied in the compounds CO, CO_2, C_2H_4, and CCl_4. The latter compound also gave the chlorine points. The nitrogen point was obtained from air and the other points from the various elements at temperatures giving suitable vapor pressures.

The limits La of the L series for light elements, computed from X-ray spectral data by the relation $La = Ka - K\alpha$, are included in Table I. A plot of $\sqrt{1/\lambda}$ against atomic number shows that both the observed (column a) and computed points from magnesium to chlorine fall on the same straight line within the probable observational error. The points "b" for these elements lie on a nearly parallel line. They indicate a new X-ray series of feeble intensity. The value of La for sodium falls above the extrapolated straight line but is consistent with Millikan's recent observation of the $L\alpha$ lines as $\lambda = 372$, and 376 A. The K limits found for carbon, nitrogen and oxygen fall close to the extrapolated

[1] Scientific Papers, No. 425.

Ka line. Theories of atomic structure indicate that the potassium points must be ascribed to M series excitation.

Experiments with radiation from solids indicate the existence of soft characteristic X-radiation with no measurable general radiation under the best vacuum conditions. Nickel shows radiation starting at 80 volts. Experimental difficulties make the results obtained from solids less convincing than those from gases.

TABLE I.

Soft X-rays from Low Voltage Arcs.

Element	Observed Potentials in volts		λ in A		Computed λ La	Remarks
	a	b	a	b		
Sodium	35.	17.	353.	726.	.....	.....
Magnesium	46.	33.	268.	374.	263.	.....
Phosphorus	126.	95.	98.0	130.	92.2	.....
Sulphur	152.	122.	81.2	101.	77.2	.....
Chlorine	198.	157.	62.3	78.6	61.9	.....
Carbon	272.	.....	45.4	.....	.....	K series limits
Nitrogen	374.	.....	33.0	.....	.....	
Oxygen	478.	.....	25.8	.....	.....	
Potassium	23.	19.	536.	650.	.....	M series limits

THE MATHEMATICAL THEORY OF THE INDUCED VOLTAGE IN THE HIGH TENSION MAGNETO.[6]

By F. B. Silsbee.

[ABSTRACT.]

THE high tension magneto is an exceedingly complex electrical system, and any attempt to treat the phenomena on a mathematical basis necessarily involves numerous assumptions. The present paper considers only the short but very important period in the cycle of operations in the magneto between the moment of interruption of the primary current and the moment when the spark gap breaks down. During this period the magnetic energy stored in the primary inductance is in part transferred to electrostatic form and charges the primary and secondary capacities. Three different types of simplified electrical models are described, each of which serves to take account of certain of the characteristics of the complete device.

[6]Scientific Papers, No. 424.

The first of these, called the double coil model, consists of two separate circuits each containing resistance, inductance, and capacity. Such a model enables one to take account of the lack of perfect coupling between the primary and secondary circuits, and shows that the resultant secondary voltage wave contains a higher frequency ripple superposed on the principal wave. The amplitude of this ripple is relatively small if the circuits are closely coupled, as is the case of most magnetos.

The second type of model considered is called the single coil model and consists of a single resistance, inductance and capacity connected in series. Such a circuit would be equivalent to a magneto if the coupling between its windings was perfect, and gives a fairly good approximation to actual conditions in many cases. The circuit is sufficiently simple so that explicit expressions can be deduced for the maximum voltage attained under various conditions. Neither of these first two models allows for the energy losses in the iron except as their resistance may be arbitrarily increased to cover this point.

A better approximation in this regard is obtained by a third or closed coil model, which consists of a primary circuit of resistance, inductance, and capacity analogous to that of the single coil model together with a tertiary circuit having resistance and inductance which is coupled magnetically to the primary circuit. This tertiary circuit represents the eddy currents in the iron and equations can be obtained for the voltage wave form of such an aggregation of circuits.

The types of wave form corresponding to each of these three models are compared qualitatively with waves actually observed at the National Physical Laboratory. The crest voltage obtained at the Bureau of Standards by interrupting various primary currents, in certain actual magnetos, is also compared quantitatively with the values predicted for the circuits by the use of the single coil and closed coil models. While the agreement is not perfect, it is sufficiently close to indicate that the models may be useful in the design of such apparatus.

Methods are also given for the measurement of the various electrical constants entering into the several types of model here described.

RECOMMENDED SPECIFICATIONS FOR LIMESTONE, QUICKLIME AND HYDRATED LIME FOR USE IN THE MANUFACTURE OF GLASS.[1]

[ABSTRACT.]

THE quality of lime to be used in the manufacture of glass depends upon the kind of glass to be made. Plate glass requires lime containing a high proportion of calcium and magnesium oxides, while cheaper glasses can make use of a less pure lime.

It is, therefore, recommended that limes be divided into three classes, containing 96, 91, and 83 per cent. of oxides of calcium and magnesium. It is also necessary that the calcium oxide content shall not vary from day to day. The maximum variation permitted is 2 per cent. All of these figures apply equally to limestone, quicklime and hydrated lime, the percentage being calculated upon the non-volatile matter of the material. Whichever material is used, it should be fine enough so that it will all pass a No. 16 sieve.

Ancient Forests in North Dakota. (*U. S. Geological Survey Press Bulletin, No. 480.*)—Fossils have been aptly called the illustrations in the great book recording the world's history, the pages of which are the layers of rock that form the outer part of the crust of the earth. By looking at some of the photographic reproductions of fossil plants we can restore in imagination the ancient vegetation of parts of the world.

Fossil plants are very abundant in the Fort Union formation, a series of Tertiary rock beds in North Dakota, where they are found in the sandstone, in the harder concretions or lenses, and in the clay between the beds of sandstone. Most of them, especially those in the clay, are preserved with remarkable fidelity. About 300 species of plants from this formation have been described, and the total number of species it contains may perhaps reach 500 or more, according to the Geological Survey.

This abundant fossil flora shows that what is now an almost treeless plain was once covered with splendid forests of hardwoods, interspersed with scattered conifers and ginkgos. The presence of numerous and at many places thick beds of lignite make it clear that in this region there were great swamps, which must have existed with but little change for long periods of time. Among the plants of this epoch were fig trees and a fan palm with leaves 5 or 6 feet across, indicating that the climate was as warm or warmer than that now prevailing on the South Atlantic slope of the United States.

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[1] Circular No. 118.

Carbon Black. (*U. S. Geological Survey Press Bulletin, No. 480.*)—The demand for carbon black, which is produced from natural gas, has greatly increased during recent years, but the supply of natural gas is rapidly decreasing, a fact that is viewed with no little alarm by the producers and consumers and that has brought about a general demand for information on the subject. Accordingly, in 1919 the Geological Survey began a canvass of the situation, and the result of this canvass is a report entitled "Carbon Black from Natural Gas in 1920," by E. G. Sievers.

Carbon black is a fluffy, velvety black pigment, frequently confused with lampblack, which is gray in color and which is produced from oil or other carbonaceous material. For many of its uses carbon black is superior to lampblack in quality, but for some uses, as for certain pigments in paints, lampblack is superior.

Carbon black has been used as a pigment in printer's ink instead of lampblack since 1864. It is also used as a coloring and reinforcing material in the rubber industry and is extensively used in the paint trade.

About 10 per cent. of the carbon black produced annually is used in the manufacture of stove and shoe polish, phonograph records, black leather, bookbinders' board, buttons, carbon and other black and gray papers, typewriter ribbons, carriage cloth, celluloid, electric insulators, cement colors, crayons, drawing and marking inks, artificial stone, black tile, and tarpaulins.

The exports now amount to 15 per cent. of the output, but before the war they amounted to 33 per cent. They will probably never again reach this amount, owing to the increased demand in the United States for carbon black.

Preparation of Carbonate-free Sodium Hydroxide.—JACOB CORNOG, of Ohio State University (*Jour. Am. Chem. Soc.*, 1921, xliii, 2573-2574), has devised the following technic for the preparation of a solution of sodium hydroxide free from carbonates. Distilled water is boiled in an Erlenmeyer flask to remove dissolved carbon dioxide, then is cooled and covered with a layer of ethyl ether from 3 to 4 centimeters in depth. Pieces of metallic sodium, not exceeding 1 centimeter in diameter, are dropped into the flask, and remain suspended in the ether. The water present in the ether slowly converts the sodium into sodium hydroxide which passes into the aqueous layer. When the proper amount of sodium has been dissolved, the greater portion of the ether is removed by means of a pipette, the remainder by boiling the solution. The resulting aqueous solution of sodium hydroxide does not yield a precipitate with an aqueous solution of barium hydroxide; hence is free from carbonates. Fire and explosions never occur during the preparation, provided the layer of ether be kept sufficiently deep, so that the suspended sodium cannot come into contact with both the air and the water at the same time.

J. S. H.

NOTES FROM NELA RESEARCH LABORATORIES.*

INTERLABORATORY PHOTOMETRIC COMPARISONS OF GAS-FILLED TUNGSTEN LAMPS.

By W. E. Forsythe and F. E. Cady.

At various times reports have been given of comparative tests made in a number of laboratories to show existing agreement in the photometry of incandescent lamps. Data of this character have been available for both the carbon and vacuum tungsten types, and it was felt that similar information on gas-filled lamps would be of value. The variety in types and efficiencies and the general use of the Ulbricht sphere for this class of lamps gives added interest to such a comparison.

The following seven laboratories participated: The Research Section and the Testing Section of the Engineering Department of the National Lamp Works, designated by R.N.L.W. and T.N.L.W.; the Photometric Laboratory of the Westinghouse Lamp Company (W.L.); the Electrical Testing Laboratories (E.T.L.); the Edison Lamp Works of the General Electric Company (E.L.W.); the Bureau of Standards (B.S.); and the Pure Science Department of the Nela Research Laboratories (N.R.L.).

The lamps tested consisted of three each of the regular commercial 100-watt, 500-watt and 1000-watt, the 1000-watt stereopticon type and the 900-watt lamp for moving picture projection. All were given a preliminary seasoning. They were first photometered at Nela Research Laboratories, then sent to the engineering Sections of the National Lamp Works and re-photometered at N.R.L. before being sent to the other laboratories. They were returned to N.R.L. and measured before being sent to the Bureau of Standards.

The results of the candlepower measurements are given in the table. Readings of current and voltage of the various laboratories checked so closely that the results are not included.

* Communicated by the Director.

TABLE I.

Values Obtained by Various Laboratories of Mean Spherical Candlepowers Reduced to Lumens.

	VOLTS	N. R. L.	R.N.L.W.	T.N.L.W.	N. B. L.	W. L.	E. T. L.	E. L. W.	N.R.L.	B. S.
100-watt		L	L	L	L	L	L	F	L	L
1	112.5	1280	1280	1295	1310	1315	1280	1320	1275	1282
2	115.4	1250	1230	1257	1275	1295	1250	1280	1240	1240
3	116.1	1310	1275	1295	1315	1320	1300	1330	1290	1287
500-watt										
1	116.6	9000	8950	9140	9050	9250	8870	8900	9050	9076
2	117.3	8950	8950	9120	9100	9250	9000	9000	9050	9064
3	114.6	8200	8200	8320	8350	8550	8860	8950	8300	8322
1000-watt										
1	117.1	18750	18850	19150	18900	19350	18760	19300	19000	18980
2	117.9	18850	19000	19160	19050	19550	19000	19500	19200	19110
3	114.5	18350								
Stereopticon										
1	115.9	21750	22150	22600	21600	22100	22100	22150	21850	22630
2	116.95	27000	27200	28030	27000	27150	27000	27950	27450	28030
3	117.55	21350	21800	22630	21600	21900	21800	22450		
Movie										
1	30 A	25900	26250	26850	25400	25650	25800	25650	26350	26530
2	30 A	23900	24550	24870	23850	23900	24000	23400	23950	23890
3	30 A	25500	25950	26320	25250	25150	25800	25750	26000	26300

In view of the relatively large differences in color between the "movie" lamps and the others and the marked differences in the filament shapes and supports the agreement in the candlepower values is somewhat surprising and very satisfactory, particularly as the tests were made according to regular commercial practices. The color differene between the 500-watt gas-filled and a 1.25 w. p. c. vacuum tungsten is about the same as that between the 1.25 w.p.c tungsten and a 4 w.p.c. carbon lamp, and there is about the same color difference between the 500-watt and the "movie" lamp.

The complete paper will be found in the *Transactions of the Illuminating Engineering Society*.

NELA RESEARCH LABORATORIES,
CLEVELAND, OHIO,
January 25, 1922.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

PERSULFATE REDUCTION.[1]

By S. E. Sheppard.

Messrs. Lumière and Seyewetz have contested (*Rev. franc. phot.*, 1921, p. 42) the acceleration of persulfate reduction by iron salts reported by the author, as also the acceleration by silver salts. The effect of these has now been determined quantitatively over a considerable range of concentrations of acid and other conductors. The persulfate used in the experiments was purified by three recrystallizations; iodimetric titration showed 99.95 per cent. S_2O_8, and ammonia titration 100 per cent. The emulsion used was chiefly Seed 23, the plates being exposed in a sensitometer, developed with para-aminophenol, fixed twice in 20 per cent. hypo with 10 per cent. neutral sulfite; they were washed in ten changes of distilled water. Each plate was treated with the same volume of fresh reducer; the plates were kept rocking in a tray at 20° C. Densities were measured before and after reduction with a Martens' photometer.

In the majority of cases the reduction was proportional of a sufficient region of the characteristic curve for the per cent. change of γ, the development factor, to be taken as the measure of reduction. Every precaution was taken to prevent contamination by traces of chloride. Under these conditions quantitative evidence for acceleration by small quantities of iron and silver salts obtained. The effect of iron salts at very low initial acidity of the reducer was not very marked, but increased rapidly as the acidity increased, then again diminished and became negligible at an acidity of about .5 per cent. H_2SO_4. A quite similar effect of iron salts was found for the solution of pure precipitated metallic silver by persulfates.

The catalytic rôle of ferric and argentic ions appears to be explicable as follows: The writer has found that the high poten-

* Communicated by the Director.

[1] Communication No. 126 from the Research Laboratory, Eastman Kodak Company, and published in *Phot. J.*, Dec., 1921, p. 450.

tials of persulfate solutions correspond to an unstable oxygen electrode, according to the irreversible reaction,

$$S_2O_8'' + H_2O = 2HSO_4'' + O.$$

In agreement with the results of Lorenz (1906) and of Schoch (1910) on oxygen electrodes in presence of oxidizable metals, the writer considers that the first step in the dissolution of silver by persulfate consists in the formation of solid silver oxide, with possible intervention of silver peroxide. Little soluble in water, the reaction is accelerated by solvents for the oxide films, such as acids and ammonia.

The catalytic effect of silver ions may consist in part in catalysis of the reaction $S_2O_8'' + H_2O = 2HSO_4' + O$, but equally, or more, by the increase of acidity in persulfate solutions in presence of silver salts. In conjunction with A. Ballard, the author found that silver salts greatly accelerate the decomposition of persulfates in solution. The velocity is approximately proportional to the concentration of the silver ion, and, as followed by increased acidity, is nearly twice as great for ammonium as for potassium persulfate. It is pointed out that this increase in acidity is probably sufficient to account for the action of silver and ferric ions, which operate indirectly as promoters of acidity. This explains at the same time their relatively diminished effect as the acidity is independently increased.

It is pointed out that these results may contribute also to the explanation of the differential reduction with persulfates, inasmuch as local differences in effective hydrogen ion concentration may occur in a gelatin layer, according to the proportion of silver to gelatin. This would be in consequence of "buffering" action by the gelatin. The author criticizes Lumière and Seyewetz's theory of differential reduction, which is incompatable with the fact that plates exposed from the back give the same result as those exposed normally. In this connection he points out that different types of emulsions give different results in persulfate reduction. The investigation of this, and of the causes of differential reduction with persulfate is left for a later paper.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

A REPORT ON THE ZAMIA STARCH SITUATION.[1]

By J. F. Clevenger.

[ABSTRACT.]

Zamia floridana DC., growing in the vicinity of Miami, Florida, has an enlarged tuberous-like stem below the level of the ground, which enables the plant to withstand the fires that occur frequently in that region. Analysis of the rhizomes showed that it contained over 37 per cent. of starch. Attempts to cultivate the plant on a commercial scale have so far been unsuccessful, possibly due to the absence in the soil of the organisms forming the root tubercles. The starch prepared from the rhizomes is used by the natives as a food in limited amounts in making crackers, biscuits, and other food products requiring starch. The manufacturer depends for his supply chiefly upon collections by the local residents. Zamia starch has been marketed under the designation "Florida arrowroot." True arrowroot starch is obtained from Maranta root. This double use of the term arrowroot has led to confusion in the trade; hence the name "Florida arrowroot starch" or "Florida arrowroot flour" should not be used. The designation "flour" is distinctly objectionable, since during the process of manufacture tissue elements are practically eliminated. It is believed that the name "Zamia starch" should be applied only to the product obtained from Zamia plants.

DISTRIBUTION OF CERTAIN DRUGS BETWEEN IMMISCIBLE SOLVENTS.[2]

By W. O. Emery and C. D. Wright.

[ABSTRACT.]

STUDIES have been made of the effect of temperature and concentration on the distribution of caffeine between water and chloroform. The effect of the presence of other solutes in the

* Communicated by the Acting Chief of the Bureau.

[1] Published in *J. Am. Pharm. Assoc.*, 10 (1921): 837.

[2] Published in *J. Am. Chem. Soc.*, 43 (1921): 2323.

aqueous layer on distribution has been determined at 25°. The solubility of caffeine in water and certain aqueous solutions has been measured at 25°. Further proof of the existence of molecular compounds of caffeine with sodium salicylate and sodium benzoate in aqueous solution has been obtained by cryoscopic measurements. The distribution of antipyrine has been determined under similar conditions. The solubility of p-acetoxy-acetanilide in water and chloroform has been measured at 25°. Its distribution between water and chloroform has likewise been determined. Comparison of the distribution curves for caffeine and antipyrine between water and chloroform confirms the earlier assumption that the distribution ratios of these substances are nearly if not quite identical.

THE RELATIVE TOXICITY OF STRYCHNINE TO THE RAT.[3]

By E. W. Schwartze.

[ABSTRACT.]

THE results of a series of experiments on the toxicity of strychnine to the rat are compared with the results which have heretofore been recognized for other animals or can be deduced for them from miscellaneous data in the literature. The comparative pharmacology of strychnine in mammals is outlined. The age (development) markedly influenced the toxicity of strychnine and the type of spasms produced. The rate of disposal of strychnine by the rat and its absorption from the stomach are discussed. The practical application of the observed phenomena is considered.

YEASTS AND OIDIA IN HIGH-GRADE EXPERIMENTAL BUTTER.[4]

By William R. North and George F. Reddish.

[ABSTRACT.]

FOLLOWING a previous study by Redfield which fixed upon the numbers of yeasts and oidia in cream as indices of age and unfavorable conditions of storage and transportation, the authors examined a series of commercial, high-grade butter samples made in the Grove City Creamery. The examination consisted in micro-

[3] *U. S. Department of Agriculture Bulletin 1023*, issued January 9, 1922.

[4] Published in *J. Dairy Sci.*, 4 (1921) : 510.

scopic counts of the numbers of yeasts and oidia per cubic centimeter of the mixed cream going into the churn. In contrast to these figures microscopic counts were made from the whey extruded from melted samples of the resulting butter. Very few of the cream samples examined showed yeasts in excess of 5000 per cubic centimeter, and in no case did the figures exceed 75,000 per cubic centimeter. By the microscopic method used no oidia were found since the number must exceed 5000 to be counted. Cultures showed, however, yeasts and oidia to be present in small numbers. Counts made from the butter showed the numbers of yeasts and oidia to be consistently less than 5000 per cubic centimeter when freshly made. Careful experiments in shipping these butters and storing them under refrigerator temperatures showed that yeasts multiply readily in moderately salted butter whenever the temperatures of transportation or storage permit, whereas oidia were restrained from growing by the salt present. The count of oidia, therefore, in such butter is attributable to the cream and more or less indicative of the condition of that cream before manufacture. The small numbers of yeasts and oidia found in these high-grade creamery butter samples scoring 93 or over are in sharp contrast to the numbers found by Redfield in a large series of butter and cream samples in a centralizer creamery whose output regularly scored 88 and 89.

Alaska Once Subtropical. (*U. S. Geological Survey Press Bulletin, No. 481.*)—The ancient vegetation of the Arctic region, as is shown by a study of its fossil plants, indicates that its climate was once very unlike that which prevails there now. Instead of consisting of a handful of small plants struggling for life amid snow and ice in a scant, almost perpetually frozen soil, its vegetation was abundant and luxuriant and included ferns and palm-like plants that grow only in a mild and probably frostless climate. This vegetation flourished in the Arctic region from at least late Paleozoic to middle Cenozoic geologic time, millions of years ago, before man existed. Although these lands are now so inhospitable and are rarely visited, the Geological Survey has gathered a large amount of information concerning their fossil floras.

A study of the coal beds of the Cape Lisburne region has incidentally disclosed many fossil plants. These coal beds are extensive and are the only known commercially valuable mineral resources of that region. A little coal is occasionally mined for vessels that are short of fuel, which, as there is no harbor, lie offshore and perilously load on a few sacks of coal by means of lighters.

Cape Lisburne is the bold headland which marks the northwest end of a land mass that projects into the Arctic Ocean from the western coast of Alaska about 160 miles north of the Arctic Circle and about 300 miles directly north of Nome. Even Cape Lisburne is by no means the northern limit of the fossil plants of this nearly tropical vegetation, for they have been found in the rocks 180 miles northeast of Cape Lisburne.

Antirachitic Vitamine.—Results obtained in a study of experimental rickets in rats, made by E. V. MCCOLLUM, NINA SIMMONDS, P. G. SHIPLEY and E. A. PARK, of Johns Hopkins University (*Jour. Biol. Chem.*, 1922, l, 5-30), support the view that cod liver oil contains an antirachitic vitamine as well as fat-soluble A. The fat-soluble A vitamine promotes growth and prevents the occurrence of xerophthalmia (an eye disease), while the antirachitic vitamine prevents the occurrence of rickets. McCollum and his associates find that "cod liver oil contains in abundance some substance which is present in butter fat in but very slight amounts, and which exerts a directive influence on the bone development and enables animals to develop with an inadequate supply of calcium much better than they could otherwise do."

J. S. H.

Precautions in the Use of Nessler Solution.—Nessler solution is an aqueous solution of potassium mercuric iodide rendered alkaline by addition of the hydroxide of a fixed alkali. It reacts with solutions of ammonium salts to yield a yellow solution containing dimercuric ammonium iodide. Extensive use is made of this reaction in analytic chemistry for the quantitative determination of ammonia colorimetrically. At times a cloud or precipitate may also form and interfere with the determination. According to CLARENCE E. MAY and HARRY P. ROSS, of Indiana University (*Jour. Am. Chem. Soc.*, 1921, xliii, 2574-2575), this phenomenon may be avoided by taking certain precautions. Only distilled water may be used for dilutions; tap water, which has been rendered ammonia-free, is unsatisfactory. Prior to use, the glass vessels, in which the reaction is carried out, should be washed with chemically pure nitric acid, then with water in order to remove the mercury film from a previous determination. Not over 1.0 milligram of ammoniacal nitrogen should be present in 150 c.c. of solution. The proper volume of Nessler solution should be added rapidly and at one time, never in several successive portions. An intimate mixing of the solutions occurs instantaneously without agitation. In fact, stirring and shaking must be avoided. Twenty minutes after addition of the reagent, water may be added gently to dilute to any desired volume.

J. S. H.

NOTES FROM THE U. S. BUREAU OF MINES.*

WATER GAS TAR EMULSIONS.

By W. W. Odell.

ALMOST every gas plant where carbureted water gas is made experiences some difficulty in separating the tar from the water condensing from the gas. The fact that this trouble is ever present in some plants, and seldom present in others, indicates that certain operating variables have considerable to do with the formation of separable tar-water emulsions. The U. S. Bureau of Mines, in coöperation with the University of Illinois Engineering Experiment Station, the Illinois State Geological Survey, and the Illinois Gas Association, has investigated the causes for emulsion difficulties in water gas plants.

It was found that the tar differs in composition and quality according to the part of the cooling system from which the sample is collected, and that usually the tar which condenses from the gas in the early stages of cooling forms the most stable emulsions. Among the factors that affect the quality of the tar are the temperature in the checker chamber, spacing and condititon of checker-brick; rate of input, distribution, and character of the carbureting oil used, quantity of excess steam used, character of condensing system and rate of cooling the gas. Fuller details are given in a report that will be published by the Bureau of Mines.

MILLING METHODS IN TRI-STATE ZINC DISTRICT.

By W. H. Coghill and C. O. Anderson.

THE Bureau of Mines, in coöperation with the Missouri School of Mines and Metallurgy, the Miami School of Mines, Oklahoma, and operators of the Tri-State zinc district, is investigating milling methods in that district with a view to improving recoveries and decreasing losses of mineral in the tailing. The chief problem confronting the operators is the loss of zinc in the chats (locked grains of blende and flint). Generally the locked blende is in sufficiently large grains to permit use of gravity separation,

* Communicated by the Director.

but much of the flint contains such minute specks of blende that gravity separation is out of the question, although the assay indicates a desirable grade of ore. The operators have made heroic efforts to recover the locked minerals, but in general, the mill systems developed have not been satisfactory, and are more or less complicated. The Bureau's metallurgists have succeeded in developing a new type of jig, which has given good results in the laboratory tests for control work in mill sampling and testing. Tests on a larger scale with this jig are now under way. Fuller details will be found in a recent paper issued by the Bureau in mimeograph form.

MOMENTARY HEATING OF INFLAMMABLE COAL DUSTS.

By Guy B. Taylor.

IN investigations on the explosibility of coal dust, by the Bureau of Mines and others, one of the unsettled points is whether the coal-dust particles in an explosion unite directly with the oxygen of the air, or whether predistillation of gas from the coal-dust particle takes place and is a factor in propagating the explosion from particle to particle.

Experiments in the Bureau's laboratories, in dropping a hot metallic body through a dust cloud in an inert gas (nitrogen) seemed to show that predistillation, if any, was negligible, although when air was present an explosion would ensue. Experiments were also tried in which the coal dust was momentarily heated by passing it through an electrically heated porcelain tube, the dust being brought into suspension by a blast of hot inert gas (nitrogen) passed through the tube. These experiments also seemed to show no distillation. Results of a third series by a bomb method were inconclusive. It was not practicable to continue this line of work, but the results have been published in mimeograph form for the benefit of others who may be interested in carrying on further experimentation.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 15, 1922.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 15, 1922.

DR. WALTON CLARK, President of the Institute, *in the Chair.*

The Board of Managers submitted its report. The report recorded the election to membership of Messrs. Clifford Whitman Bates, Charles Douglas Galloway and William E. Saunders; lectures before Sections by L. W. Austin, Ph.D., Head, U. S. Naval Radio Research Laboratory, Bureau of Standards, Washington, District of Columbia, on "Recent Developments in Radio Communication"; by L. J. Henderson, M.D., Professor of Biological Chemistry, Harvard University, Cambridge, Massachusetts, on "Applications of Physical Chemistry to the Physiology of Breathing"; lecture before the Stated Meeting January 18, 1922, by Honorable William D. B. Ainey, LL.D., L.H.D., Chairman of the Public Service Commission of Pennsylvania on "The Highway System of the State of Pennsylvania"; and additions to the library by gift, 42 volumes and 156 pamphlets, by purchase 44 volumes.

L. J. Briggs, M.S., Ph.D., Chief of Engineering Physics Division, Bureau of Standards, Washington, District of Columbia, presented the paper of the evening on "The Resistance of the Air." Wind-tunnels for obtaining air-streams of known velocity were described as well as aerodynamical balances for measuring air forces on a model; reference was made to the air-resistance equation and dynamical similarity in air-resistance measurements. Consideration was given to the air-resistance of bodies of various forms and to air-foils. Reference was also made to the problem of the measurement of the resistance of projectiles. The subject was illustrated by lantern slides.

A unanimous vote of thanks was extended to Doctor Briggs.

Adjourned.

R. B. OWENS,
Secretary.

REPORT OF THE PRESIDENT FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1921.

TO THE MEMBERS OF THE FRANKLIN INSTITUTE:

This writing is the report which your Board of Managers has instructed me to make to you of the affairs of the Institute for the Institute year ending September 30, 1921.

The work of the Institute was carried on through the year successfully as the Management think, and as you may learn in detail from a reading of the reports of the several committees of the Board and of the Institute as they will appear in the 1922 Year Book. As is customary in the Managers' report, we quote briefly from the Committee reports, with such comment as seems useful.

The Committee on Exhibitions (Mr. Benjamin Franklin, Chairman) reports on the present status of the Sesqui-Centennial Exhibition as it affects The Franklin Institute. This report does not call for any specific comment here.

The Committee on Museum (Mr. Outerbridge, Chairman) reports the addition to the Museum of models and apparatus of great historic interest, among them the air pump of Dr. Joseph Priestley, presented by Mr. Coleman Sellers, Jr.; an odometer made and used by Isaiah Lukens, one of the early Vice-presidents of the Institute, presented by Mr. Henry R. Towne; a printing telegraph, the invention of George H. Phelps, presented by the Pennsylvania Hospital; and an Oertling balance, with weights, presented by Dr. Harry F. Keller.

Most of our models are now so crowded on the shelves of the Institute that they are practically not available to the student, the inventor and the mechanician. We have reason to believe that we will soon be able to store and properly display our many valuable models and pieces of apparatus of historic value in a building owned and operated by the Institute.

The report of the Committee on Sectional Arrangements (Dr. Keller, Chairman) tells in detail of the lectures—nineteen in number—delivered during the year before the various sections of the Institute. This report is interesting to read, but offers little opportunity for presentation in brief.

The Committee on Meetings (Dr. Alleman, Chairman) reports the lectures delivered before the Institute. Eight stated meetings were held during the year. This report, like that of the Committee on Sectional Arrangements, is interesting reading, dealing with one of our very important functions, but not susceptible of summarization.

The Committee on Publications (Mr. Rosengarten, Chairman) reports, among other interesting data, the publication of the book "Physics of the Air," Dr. W. J. Humphreys, of the United States Weather Bureau, author. Of this important publication 960 copies have been sold, and the demand is still strong. The book is a recognized authority and of great value to meteorologists and to navigators of the air. It is a volume also of great interest to the layman. The Committee on Publications also reports a slight, but encouraging, decrease in the cost of publication of the JOURNAL and of the Year Book.

The Committee on Library (Dr. Creighton, Chairman) reports additions to the library of 2901 volumes and pamphlets, an increase of 393 titles over the gain of the previous year. The great sugar library bequeathed to the Institute by Mr. Lewis S. Ware—about 25,000 volumes and pamphlets—is still in temporary storage in a fire-proof warehouse. As indicated elsewhere in this report, we have the expectation of soon being able to store this valuable collection of books in a fire-proof building owned by The Franklin Institute.

From the report of the Committee on Instruction (Mr. Paul, Chairman)—being for the ninety-seventh year of our School of Mechanic Arts—we learn that the classes fell off a little, but very little, in numbers from the unusually large enrollment of the previous year. Again we found it necessary to open the school five evenings a week instead of four—our practice prior to 1919—in order comfortably to accommodate the students. The number of students graduated at the class exercises in April—being sixty-nine—is greater than in any previous year in the history of the School.

The Committee on Science and the Arts (Mr. Masland, Chairman) reports twenty cases disposed of during the year and nineteen awards made. This is an unusually large record of disposition of cases and of awards. The report refers to the publication in the 1921 Year Book of a list of all the awards made on recommendation of the Committee since its establishment in 1834. The total is 892 awards made.

The Committee on Endowment (Mr. Sellers, Chairman) gives some important data relative to the Bartol Bequest, and the very interesting information of another bequest so far not reported to you. Mr. George Theodore Roberts, who died in March, 1921, made The Franklin Institute one of the residuary legatees of his large estate, his daughter having a life interest in the property. Mr. Sellers has been advised that the Institute's interest as one of the residuary legatees probably amounts to $40,000.

The Committee on Stock and Finance (Mr. Forstall, Chairman) reports a very sound financial condition, although for the immediate present our operating expense exceeds our operating revenue. This is a condition anticipated by your Board when we told you a year ago of the then increase in our balance of assets over liabilities, and that at the end of the year, for the first time in memory the Institute would be out of debt, except as between departments. Our work costs more than our regular income affords, but less than our regular income plus the occasional bequests applicable to operating expenses, as over a period of years. In the confidence that this will be a continuing condition we have gone on with our work, spending what was necessary to its efficient conduct. So we propose to go on with it as long as we have available funds, or bank credit or salable property—never to the extent of imperilling creditors' interests—or of using trust funds other than as designated by their donors—but otherwise to the limit of possibility. Such a course has had your approval in the past, as we hope it has your approval in the present.

The Committee on Election and Resignation of Members (Mr. Lesley, Chairman) reports a total membership of 1386, an increase of six members for the year. This increase—though small—is very welcome, being the first in several years. If the Institute depended for its financial support upon the membership dues received it would do little work indeed. Why we have less than six hundred resident members in this great industrial city is a question we have not been able to answer. None of our efforts to increase our membership has had more than slight success. Of course our location is against us. When dreams come true and we are on the Parkway, perhaps our membership will increase.

The Committee to carry into effect the intent and purposes of the Henry W. Bartol Bequest was duly appointed, as instructed by your resolution of November 17, 1920. The members of the Committee are:

Mr. Charles Day, Chairman;
Dr. Joseph S. Ames, of Johns Hopkins University;
Mr. Coleman Sellers, Jr;
Dr. Arthur L. Day, of the Carnegie Institution of Washington;
Mr. C. C. Tutwiler;

with the President and the Secretary of the Institute as ex officio members.

The Committee, with the concurrent approval of the Franklin Fund and Building Committee (Mr. Howson, Chairman), anticipates that this year we will be able to begin construction of a laboratory, to be owned by The Franklin Institute, and to be occupied in part by the research work to which the Estate of Henry W. Bartol is dedicated.

The principal of the Bartol Bequest available as of December 31, 1921, is approximately $1,300,000, and there is an accumulated interest fund as of that date of about $250,000. The settlements made effective with the contestants of the will will result ultimately in an addition to the fund of about $600,000. It will be some years before this fund of $600,000 will be available.

The Committee therefore finds the Bartol Bequest with an accumulated income of $250,000 and the expectation of a continuing income of from $75,000 to $80,000 per annum, to later increase to probably $100,000 per annum.

It is proposed, with the approval of the Franklin Fund and Building Committee and of the Board of Managers of the Institute, and as soon as the necessary legal and other procedures may be observed, to erect a laboratory on three of the twelve lots owned by the Institute on Nineteenth Street between Cherry and Race Streets. It is expected the laboratory will cost approximately $250,000, of which $100,000 will be provided from the accumulated income from the Bartol Research Fund, and $150,000 by the Institute through its Franklin Fund and Building Committee. This laboratory, which will be of a character to harmonize with the other buildings of The Franklin Institute group which we expect will ultimately occupy the other lots owned by the Institute at this location, will be sufficient to house the Bartol research work and all of the chemical and physical laboratory work of the Committee on Science and the Arts and of all other departments of The Franklin Institute.

The equipment, except for certain standard apparatus that is immediately indicated as necessary, is to be installed gradually as the necessities of the research work in hand indicate. The contribution of the Bartol Research Fund to the cost of the laboratory building is measured by what we estimate it would cost the Committee on the Bartol Bequest to erect a building suitable for its work at a less expensive site. The building being owned by The Franklin Institute, the Bartol Research Bequest will be given a right to use the laboratory in its work for a period that may be definitely fixed or may be unlimited, according as we shall decide later.

The management of the work of the Bartol Research Committee will be in the hands of Dr. R. B. Owens, Director, reporting to the Committee, and with such research professors and fellows as it may be found necessary or important to engage. A sub-committee of Dr. Owens, Chairman; Dr. Joseph S. Ames, and Dr. Arthur L. Day, has been appointed to engage the necessary staff.

The Institute is to be congratulated upon this prospect of soon starting work on a building that will house a portion of its activities, and as we confidently anticipate, will be but the first step toward the construction of a group of buildings, now to be discussed herein.

Your Board thinks it wise at this time, and in this connection, to advise you of its hopes and ambitions for the future housing and conduct of the work of the Institute.

The laboratory necessary to the proper housing of the Bartol research work, and of the chemical and physical work of the Committee on Science and the Arts, and of other departments of the Institute, has had reference herein. Our hope is that ultimately this laboratory will be one of a group of three buildings. We look forward to the date of the realization of our hopes and expectations, to see a building at the corner of Nineteenth Street and the Parkway, exteriorly worthy of a place among the noble structures then to be its neighbors and bearing a dignity worthy of the great name it will bear, and interiorily sufficient and suitable to the proper housing and conduct of all the Institute's work and equipment, except that the laboratory and museum are to be otherwise sheltered. The third building of the little group devoted to the promotion of the mechanic arts, when our hopes find fulfilment, will be a so-called "Scientific and Technical Museum." In it will be properly arranged and connected for illustration and for operation, the many important models and facsimilie apparatus now possessed by the Institute, and the multitude of such other things of interest to a follower of the mechanic arts as we have assurance will come to us when we are prepared properly to care for them. We believe that such a museum has no example in America. The American student, historian, mechanician or inventor, desiring to trace the development of an art through the study of concrete examples, must now journey to Europe to find what we will be able to present to him when our proposed museum is in operation.

Such a group of buildings so equipped will be without counterpart in America. The value of the opportunity therein offered to the student, the scientist and the mechanician cannot be exaggerated in statement. To provide and equip these buildings is upon the program your Board now presents to you—the membership of the Institute.

Does this appear an unduly ambitious program? We think it is not, and we ask you, members of the Institute, when considering it to remember that the Institute's wagon has ever been hitched to a star, and that, so drawn, it has come nearly to the hundredth year post on its road, maintaining still, as we believe, the virility and enthusiasm of youth and as capable as ever of vision and of accomplishment.

You will note that however ambitious our program may appear, it comprehends no departure from the scheme of usefulness laid out by our founders. With greater opportunity, more funds, and the example and experience of nearly a hundred years of service for our guidance, we of this generation may reasonably hope for ourselves and our successors to extend the benefits of the Institute's work to an ever widening circle—the interest being still confined to the Promotion of the Mechanic Arts—the vision being still that which inspired the founders and the generations of workers who have brought the Institute down the the century to our day and custody. We remember with pride what of public good these men accomplished—generally, if not always—with very limited financial resources—their one unlimited resource the spirit of devotion. May we not confidently expect our successors in membership to have this spirit of devotion in equal measure, and, with the experience and example of our predecessors to inspire and guide them, to produce results, as expressed in usefulness to the public, somewhat commensurate with the financial resources and equip-

ment we leave to them? We of your Board of Managers believe we may so confidently anticipate greater results to come with more nearly adequate funds and equipment, and so believing, we submit our program. In the absence of objection we shall regard it as having your approval. We do not doubt that the Institute will ultimately reach the goal this program sets for it. When—no one can say. It is probable that the first step—the laboratory building—will be begun this year, and that the research work of the Bartol Foundation will be fully under way in it at the celebration of our centennary in 1924.

We now own all the land useful in carrying out our full program, except for one lot, and without this lot we can carry out our program, with somewhat reduced convenience of operation. Our funds dedicated to buildings will nearly be exhausted by the laboratory cost. So from the completion of our laboratory our building program must await the acquisition of more funds. The main building, equipped and occupied, will cost approximately one million dollars. The next step in our program is the erection and equipment of the scientific and technical museum, costing probably two hundred and fifty thousand dollars. The order of erection of these two buildings—the main building and the museum—might be reversed and the museum be the first to follow the laboratory.

Since we will have greater operating expenses in the new buildings, and since we cannot greatly increase our regular income, we think we should not venture on the next step of our program—the erection of the larger building—until we have a larger regular income dedicated to operating expenses. We think the Institute would not be justified in undertaking the full program now before us without an added endowment of a million dollars.

Thus the roughly estimated cost of completing our full program is two and a quarter million dollars. We believe that in the example of the founders of the Institute we may find the guide to the realization of our ambition. Efficient work in the public interest, the full utilization of what property has been confided to us, will in the future, as in the past, meet the approval of people seeking to dedicate some part of their accumulated wealth to the promotion of the mechanic arts. Always a part of our program is the efficient and economic application of our financial resources to such ends. We do not doubt that living to this part of our program in the future, as we have striven to live to it in the past, will bring such increase in financial resources as will make possible the full realization of the ambitions your Managers have herein discussed.

Respectfully submitted,

WALTON CLARK,
President.

PHILADELPHIA, January 18, 1922.

STANDING COMMITTEES, 1922.

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.

Robert W. Lesley, Chairman.
Gellert Alleman.
Alfred W. Gibbs.
Clarence A. Hall.
Marshall S. Morgan.

EXECUTIVE.

E. H. Sanborn, Chairman.
Charles Day.
Walton Forstall.
Alfred W. Gibbs.
Alfred C. Harrison.

INSTRUCTION.

Lawrence T. Paul, Chairman.
George A. Hoadley.
Harry F. Keller.
Edward V. McCaffrey.
James S. Rogers.

SECTIONAL ARRANGEMENTS.

Harry F. Keller, Chairman.
Gellert Alleman.
Robert W. Lesley.
Haseltine Smith.
C. C. Tutwiler.

ENDOWMENT.

Coleman Sellers, Jr., Chairman.
G. H. Clamer.
Alfred C. Harrison.
Nathan Hayward.
Wm. Chattin Wetherill.

EXHIBITIONS.

Benjamin Franklin, Chairman.
Francis T. Chambers.
Theobald F. Clark.
Charles Day.
Charles A. Hexamer.

PUBLICATIONS.

George D. Rosengarten, Chairman.
G. H. Clamer.
W. C. L. Eglin.
George A. Hoadley.
E. H. Sanborn.

STOCKS AND FINANCE.

Walton Forstall, Chairman.
Benjamin Franklin.
Alfred C. Harrison.
James S. Rogers.
E. H. Sanborn.

OF THE INSTITUTE.

LIBRARY.

Charles E. Bonine.
G. H. Clamer.
H. J. M. Creighton.
W. H. Fulweiler.
Clarence A. Hall.
George A. Hoadley.
Harry F. Keller.
C. W. Masland.
Marshall S. Morgan.
George F. Stradling.

MEETINGS.

Gellert Alleman.
Joseph S. Ames.
G. H. Clamer.
Allerton S. Cushman.
Arthur L. Day.

MEETINGS (Continued).

W. H. Fulweiler.
Herbert E. Ives.
A. E. Kennelly.
Ralph Modjeski.
George D. Rosengarten.

MUSEUM.

Hugo Bilgram.
Arthur L. Church.
Charles Day.
W. C. L. Eglin.
George A. Hoadley.
C. W. Masland.
A. E. Outerbridge, Jr.
Charles Penrose.
H. H. Quimby.
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 1, 1922.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 1, 1922.

MR. CHARLES W. MASLAND, *in the Chair.*

Dr. James Barnes was unanimously elected Chairman for the year 1922.

The following reports were presented for final action:

No. 2775: Automatic Die Cutting Machine. The Edward Longstreth Medal to Mr. Joseph Keller, of Brooklyn, New York.

No. 2777: Chlorinator. The Edward Longstreth Medal to Messrs. Martin F. Tiernan and Charles F. Wallace.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 12, 1922, at eight o'clock, with Mr. W. H. Fulweiler in the Chair. The minutes of the previous meeting were read and approved.

Ralph H. McKee, Ph. D., Professor of Chemical Engineering in Columbia University, New York City, delivered a lecture on "Gasoline from Oil Shale." The possible American sources of motor fuel were considered. The American deposits of oil shale, the destructive distillation of such shale, and the production of gasoline from the crude distillate were described. The lecture was illustrated with lantern slides and with specimens of typical oil shales and shale oils.

The communication was discussed by Doctors Porter and McKee, Messrs. Fulweiler, Tutwiler, Lesley and others. On motion of Mr. Tutwiler, a vote of thanks was extended to Doctor McKee. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 2, 1922. The meeting was called to order by Prof. James Barnes. The minutes of the previous meeting were approved as printed in the JOURNAL.

The paper of the evening on "Recent Developments in Radio Communication" was presented by L. W. Austin, Ph.D., D.Sc., Head, U. S. Naval Radio Research Laboratory, Bureau of Standards, Washington, D. C. Attention was given to the recent development in and the present status of long distance radio communication; its methods, its problems and difficulties, its reliability and limitations; with the laws of transmission and their experimental verification. Facts were presented regarding the principal high power stations of the world now in operation or under construction. Announcement was made of plans for

long distance communication, and with long distance radio in the future. The subject was illustrated by lantern slides.

After a brief discussion a unanimous vote of thanks was extended to the speaker.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 8, 1922.)

HONORARY MEMBERSHIP.

DR. RALPH MODJESKI, New York City and Philadelphia.
ADMIRAL WILLIAM S. SIMS, U. S. N.
SIR JOSEPH JOHN THOMSON, Trinity College, Cambridge, England.

RESIDENT.

MR. CLIFFORD W. BATES, 403 N. Narberth Avenue, Narberth, Pennsylvania.
MR. CHAS. DOUGLAS GALLOWAY, 8409 Anderson Street, Chestnut Hill, Philadelphia, Pennsylvania.
MR. WM. E. SAUNDERS, U. G. I. Company, Broad and Arch Streets, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

DR. GEBHARDT BUMCKE, Trades Oil Products, Inc., 172–180 Frelinghuysen Avenue, Newark, New Jersey.
MR. WM. J. BURGESS, Pennsylvania Coal Products Company, Petrolia, Pennsylvania.
MR. GEO. E. KINNIER, 37 W. Church Street, Bethlehem, Pennsylvania.
MR. FRANKLIN P. MCCONNELL, care of Day and Zimmermann, Inc., 611 Chestnut Street, Philadelphia, Pennsylvania.
MR. J. MILLIKEN, President, Pittsburgh Testing Laboratory, P. O. Box 1115, Pittsburgh, Pennsylvania.
MR. C. E. SARGENT, 909 Twentieth Street, Rock Island, Illinois.
DR. LESLIE DENIS SMITH, 2472 Ontario Road, N. W., Washington, D. C.

NECROLOGY.

Dr. Charles Baskerville, College of City of New York, New York City, New York.

Mr. Frank H. Clement, Land Title Building, Philadelphia, Pennsylvania.

Mr. John C. Pennie, 165 Broadway, New York City, New York.

LIBRARY NOTES.

PURCHASES.

American Institute of Chemical Engineers.—Transactions, 1920. 1921.

CURIE, MARIE SKLODOWSKA (Mme. Pierre).—La Radiologie et la Guerre. 1921.

FAJANS, K.—Radioaktivität und die neueste Entwickelung der Lehre von den chemischen Elementen. 1921.

FREUND, IDA.—Experimental Basis of Chemistry. 1920.

FRIEND, J. NEWTON.—Text-book of Inorganic Chemistry. Iron and its Compounds. 1921.

HOLLEMAN, A. F.—Text-book of Inorganic Chemistry. 1921.

HOLLEMAN, A. F.—Text-book of Organic Chemistry. 1920.

KÖGEL, P. R.—Die Palimpsestphotographie. 1920.

Scientific Papers of the Hon. Henry Cavendish, 2 vol. 1921.

SILBERSTEIN, L.—Elements of Vector Algebra. 1919.

Society of Chemical Industry.—Reports on the Progress of Applied Chemistry. 1917–20.

GIFTS.

Allis-Chalmers Manufacturing Company, Steam Turbine and Alternator Units and Power Transformers. Milwaukee, Wisconsin, 1921. (From the Company.)

American Annual of Photography for 1922. New York City, New York, 1921. (From Mr. Frank V. Chambers.)

American Steel and Wire Company, Booklet of Stucco Houses. Chicago, Illinois, 1921. (From the Company.)

Baker Brothers, Booklet 121 of Boring and Drilling Machines and Keyseaters and Slotters. Toledo, Ohio, no date. (From the Company.)

Biddle, James G., Catalogue 940, "Megger" Testing Sets. Philadelphia, Pennsylvania, no date. (From Mr. Biddle.)

Bristol Company, Preliminary Catalogue No. 1501. Waterbury, Connecticut, 1921. (From the Company.)

Canadian Department of the Interior, Water Resources Papers Nos. 28, 29 and 30. Ottawa, Canada, 1921. (From the Department.)

Canada Department of Mines, Production of Coal and Coke in Canada and Production of Copper, Gold, Lead, Nickel, Silver, Zinc, and Other Metals in Canada. Ottawa, Canada, 1921. (From the Department.)

Canadian Minister of Public Works, Report for 1921. Ottawa, Canada, 1921. (From the Canadian Minister.)

Centrifugal Fan Company, Pamphlet of Ventilation's Part in a Better World. Newark, New Jersey, no date. (From the Company.)

Clark Tool Works, Incorporated, The Clark Compound Metal Cutting Band Saw. Belmont, New York, 1921. (From the Works.)

Coffin Valve Company, Coffin Balanced Needle Valve. Neponset, Boston, Massachusetts, no date. (From the Company.)

Colgate University, Annual Catalogue 1921–1922. Hamilton, New York, 1921. (From the University.)

College of Physcians, Transactions, vol. 42. Philadelphia, Pennsylvania, 1920. (From the College.)

Connelly, The D., Boiler Company, Boilers. Cleveland, Ohio, 1921. (From the Company.)

Cummings Machine Company, Catalogue No. 65 of Foundry Equipment. Minster, Ohio, no date. (From the Company.)

Cutler-Hammer Manufacturing Company, C-H Magnetic Clutches. Milwaukee, Wisconsin, no date. (From the Company.)

Departamento de Agricultura y Trabajo, Circulars No. 41, 42, 43, 44 and 45. San Juan, Porto Rica, 1921. (From the Department.)

Edison Swan Electric Company, Limited, Catalogue Ab.2 of Lighting Accessories. London, England, 1919. (From the Company.)

Foote-Burt Company, Catalogue on Drills. Cleveland, Ohio, no date. (From the Company.)

Gardner Machine Company, Gardner Improved Abrasive Disc. Beloit, Wisconsin, no date. (From the Company.)

Gilfillan Brothers, Inc., Catalogue No. 7, Gilfillan Products. Los Angeles, California, 1920. (From Gilfillan Brothers.)

Griscom-Russell Company, Bulletin 903 and Leaflet No. 6. Philadelphia, Pennsylvania, no date. (From the Company.)

Haiss, George, Manufacturing Company, Inc., Booklet 719 of Haiss Buckets. New York City, New York, no date. (From the Company.)

Hans Renold, Ltd., Chains and the Machine Tool. Didsbury, England, 1921. (From the Company.)

Harrison Safety Boiler Works, Cochrane Separators. Philadelphia, Pennsylvania, 1913. (From the Works.)

Hart Roller Bearing Company, Value *versus* Competition. Orange, New Jersey, 1921. (From the Company.)

Hauser-Stander Tank Company, Wooden Tanks for Every purpose. Cincinnati, Ohio, no date. (From the Company.)

Hayward Company, Pamphlet 617 of Hayward Buckets. New York City, New York, no date. (From the Company.)

Hoffman Specialty Company, Hoffman Venting Valves for Every Service. Waterbury, Connecticut, no date. (From the Company.)

Hunter Saw and Machine Company, Catalogue E of Hunter Saws and Tools. Pittsburgh, Pennsylvania, 1921. (From the Company.)

Ilg Electric Ventilating Company, Universal Blowers and Motor Propeller Fans. Chicago, Illinois, 1921. (From the Company.)

Independent Concrete Pipe Company, Bulletin No. 9, Reinforced Concrete Pipe. Indianapolis, Indiana, no date. (From the Company.)

India Geological Survey, vol. iii, Memoir No. 2, The Brachiopoda of the Namyau Beds, Northern Shan States, Burma. Calcutta, India, 1917. (From the Department.)

India Meteorological Department, Monthly Weather Review for February and March, 1918. Calcutta, India. (From the Department.)

Institution of Civil Engineers, Minutes of Proceedings with Selected Papers, vol. ccix. London, England, 1921. (From the Institution.)

Instituto Geologico de Espana, Boletin Tomo 42. Madrid, Spain, 1921. (From the Institute.)

Johns Hopkins University, Magnetic Rotatory Dispersion in Transparent Liquids, Fluorescence of Mercury Vapor, Air Forces on Circular Cylinders, Axes Normal to the Wind, with Special Reference to Dynamical Similarity, Electric Strength of Air under Continuous Potentials and as Influenced by Temperature. Baltimore, Maryland, 1921. (From the University.)

Klaxon Company, Booklets on Klaxocator System and Intercommunication and Signal Equipment for Ships. Newark, New Jersey, no date. (From the Company.)

Leeds and Northrup Company, Catalogue No. 20 of Galvanometers. Philadelphia, Pennsylvania, 1921. (From the Company.)

Lister, R. A., and Company, Ltd., Catalogue of Oil Engines. Bursley, England, no date. (From the Company.)

Locomotive Feed Water Heater Company, Bulletin 5 of Feed Water Heating. New York City, New York, 1919. (From the Company.)

McIntosh and Seymour Corporation, Achievement in Motorships. Auburn, New York, 1921. (From the Corporation.)

MacLeod and Henry Company, Boiler Setting Fire Brick. Troy, New York, 1921. (From the Company.)

Maryland Academy of Sciences, Bulletins for March and June, 1921. Baltimore, Maryland, 1921. (From the Academy.)

Morris, Herbert, Incorporated, Booklet of Hoists, Trolleys and Cranes. Buffalo, New York, no date. (From the Company.)

National Commission of Fine Arts Ninth Report, July, 1919, to June, 1921. Washington, District of Columbia, 1921. (From the Commission.)

National Tube Company, Seamless Steel Tubes and Their Making. Pittsburgh, Pennsylvania, 1920. (From the Company.)

New Zealand Department of Mines, Geological Survey Branch Bulletin No. 23. Wellington, New Zealand, 1921. (From the Geologist.)

New Zealand Institute, Transactions and Proceedings, vol. liii. Wellington, New Zealand, 1921. (From the Institute.)

Nordberg Manufacturing Company, Machinery for the Mining Industry. Milwaukee, Wisconsin, no date. (From the Company.)

Philadelphia Bureau of Surveys, Annual Reports for 1919 and 1920. Philadelphia, Pennsylvania. (From the Bureau.)

Pollock and MacNabb, Ltd., Catalogue of Machine Tools. Bredbury, England, no date. (From the Company.)

Pratt and Cady Company, Incorporated, Catalogue No. 6, Valves. Hartford, Connecticut, 1921. (From the Company.)

Providence Athenæum, Eighty-sixth Annual Report. Providence, Rhode Island, 1921. (From the Athenæum.)

Rapid Electrotype Company, from Xylographs to Lead Molds, A.D. 1440–A.D. 1921. Cincinnati, Ohio, 1921. (From the Company.)

Reading Valve and Fittings Company, Flanges and Fittings. Reading, Pennsylvania, 1920. (From the Company.)

Royal Society of South Australia, Transactions and Proceedings, vol. xliv. Adelaide, South Australia, 1920. (From the Society.)

Scovill Manufacturing Company, Tube Facts. Waterbury, Connecticut, no date. (From the Company.)

Sheffield Twist Drill and Steel Company, Ltd., Catalogue of Twist Drills. Sheffield, England, no date. (From the Company.)

Smithsonian Institution, Report on the Progress and Condition of The United States National Museum. Washington, District of Columbia, 1921. (From the Institution.)

Stanford University, Register 1920–1921. Stanford University, California, 1921. (From the University.)

Stanley Works, Catalogue of Wrought Hardware. New Britain, Connecticut, no date. (From the Works.)

Station Biologique, D'Arachon, Bulletin 18. Bordeaux, France, 1921. (From the Station.)

Sterling Wheelbarrow Company, Catalogue No. 32. Milwaukee, Wisconsin, no date. (From the Company.)

Stokes, Francis J., A Treatise on Tablet and Pill Coating. Philadelphia, Pennsylvania, no date. (From the Author.)

Superheater Company, Instruction for Operation and Maintenance of Boiler Feed Pumps. New York City, New York, no date. (From the Company.)

Swedish Chamber of Commerce of the United States, Iron and Steel in Sweden. New York City, New York, no date. (From the Chamber.)

Tate Electrolytic Textile Processes, Mildew Proof Canvas. New York City, New York, 1921. (From the Company.)

Truscon–Steel Company, Booklet of Truscon Steel Sash. Youngstown, Ohio, no date. (From the Company.)

Tulane University of Louisiana, Registers for 1915 to 1921, inclusive. New Orleans, Louisiana. (From the University.)

Uehling Instrument Company, Bulletins Nos. 220 and 221 on Chimneys. Paterson, New Jersey. (From the Company.)

Union University, Medical Department Announcement for 1921–1922. Albany, New York, 1921. (From the University.)

United States Bureau of Education, Report of the Commissioner of Education for 1921. Washington, District of Columbia, 1921. (From the Commissioners.)

United States Army, Report of the Chief of Engineers, Parts i and ii. Washington, District of Columbia, 1921. (From the Chief.)

United States Navy Department, Annual Reports of the Secretary of the Navy, Surgeon General of the Navy and Paymaster General of the Navy. Washington, District of Columbia, 1921. (From the Department.)

U. S. Ordnance Department, Manufacture of Optical Glass and Optical Systems. Washington, District of Columbia, 1921. (From the Department.)

University of Illinois, Soil Report No. 19. Urbana, Illinois, 1921. (From the University.)

University of Pittsburgh, General Catalogue 1921–1922. Pittsburgh, Pennsylvania, 1921. (From the University.)

University of Wisconsin, Announcements 1920–1921 and Publications of the Washburn Observatory, vol. x, part 4. Madison, Wisconsin, no date. (From the University.)

Vacuum Oil Company, Stationary Steam Engines. New York City, New York, 1921. (From the Company.)

Vassar College, Fifty-seventh Annual Catalogue, 1921–1922. Poughkeepsie, New York, 1922. (From the College.)

Vogt, Henry, Machine Company, Bulletin R-E 2. Louisville, Kentucky, no date. (From the Company.)

Vulcan Soot Cleaner Company, Bulletins Nos. 534, 541, 547, 548, 550, 552 and 556. Du Bois, Pennsylvania, 1920. (From the Company.)

Walker, James, and Company, Limited, Packings and Jointings. New York City, New York, no date. (From the Company.)

Washington University, Sixty-fifth Annual Catalogue. St. Louis, Missouri, 1922. (From the University.)

Whitney Manufacturing Company, Booklets on Driving Chains. Hartford, Connecticut, 1921. (From the Company.)

Whitworth, Sir W. G. Armstrong, and Co., Ltd., Armstrong Whitworth Locomotives. London, England, no date. (From the Company.)

Youngstown Boiler and Tank Company, Bulletin 400. Youngstown, Ohio, 1921. (From the Company.)

BOOK NOTICES.

PETROLEUM. A treatise on the geographical distribution and geological occurrence of petroleum and natural gas, etc. By Sir Boverton Redwood, Baronet. With a foreword by Sir Frederick W. Black, K.C.B. 4th edition, reset throughout. In three volumes, with plates, numerous illustrations and many maps. Philadelphia, J. B. Lippincott Company, $21.00 net.

The author of this book has been for many years one of the foremost authorities in the field to which it is devoted. The name of Redwood is familiar to all who are interested in liquid or gaseous fuels. The death of the author at a comparatively early age occurred after the material for this edition had been largely arranged and a biographic note by Sir Frederick W. Black, gives interesting accounts of Redwood's work and the important part that he has taken in the study and development of the science and technology of petroleum and allied products. Redwood's friends, as Black states, will be pleased to know that he lived until the "oil age" was well developed, and quotes Curzon's phrase that Great Britain and her allies had "floated to victory on a sea of oil."

Oil has often been spoken of as a quieter of disturbances. To pour oil on troubled waters has been a proverbial expression for a long time, but it seems that at present, oil is rather troubling the waters of diplomacy than pacifying them. A lull in the agitation has seemingly been due to the interest the world has been taking in the conference at Washington, but after the problems are for the time settled there, and diplomats return to their own lands, it is probable that mercantile interests, especially in connection with the oil-burning ship and the internal combustion engine, will arise and be the subject of correspondence

pourparlers, protests, protocols and other apparatus of international manipulations. There is no doubt that Great Britain has been aiming to secure a large control of oil production. For this action no one can blame British statesmen, seeing how dependent the nation is on efficient ships and control of the sea. Redwood, indeed, held that whatever might be the applicability of oil in general, it is a necessity for the British navy. He predicted that oil will transform ocean traffic, and that new forms of oil engines will enable the submarine to be used as a merchant vessel.

Turning to the book itself, we find, as would be expected, that it contains an enormous amount of detailed information covering every phase of the question. Many hands have been active in bringing up the sections to meet present knowledge and requirements. All those who have thus aided are duly acknowledged in the preface. The work begins with a historical introduction, in which the earliest definite references to the materials are collected, but such references are not only scanty, but more or less uncertain on account of the lack of definite knowledge of the meaning of ancient words. Some of the solid substances consisting largely of hydrocarbons and their oxidation products were certainly used in very ancient times. Indeed, we have in Babylonian bricks an account of the building of the ship for use during the flood, in which the complaint is made that seven barrels of pitch were charged for when only three were used. After the historical note, the localities in which petroleum and natural gas were found are described, and a map of the world on Mercator's projection shows at a glance the distribution of these fields. Of course, these indications cover only the points at which such deposits have been found. Many other localities probably exist, for the discovery of oil and gas has often been somewhat catastrophic.

The question of the duration of oil-supply is a momentous one, and some space is given to the discussion of it. It is there stated that the production of oil and gas is still going on in some places, but the districts which are being most largely worked are not being recuperated in appreciable amount, and when they are exhausted will be permanently barren. The strata yielding oil and gas are geologically identical, the latter accumulating in the domes or arches in the deposits. The most productive wells in the United States obtain gas from very old rocks, but the Russian yields are from later geologic formations.

The origin of petroleum and gas has been extensively discussed. The Engler–Höfer theory which ascribes the production to the decomposition, in place of the fatty matters of marine organisms—animal and vegetable—at one time quite popular, is stated to be apparently losing support.

The first volume closes with accounts of the physical and chemical properties of the products, in which an enormous amount of statistical material is accumulated. The second volume takes up the methods of obtaining and refining the materials and the methods of transport, storage and distribution. Sixty-six pages are devoted to the shale-oil and allied industries, a welcome and important chapter in view of the attention that is now being given to these sources of liquid and gaseous fuels.

The analytical methods and the practical applications are included in the

third volume, which contains also a summary of the laws and regulations and extensive statistics of production, with data concerning the duties levied on the raw materials and their products. A local flavor is given by two pages devoted to the regulations for motor boats on the Thames. A bibliography of 261 pages and an index of 35 closely, but clearly, printed pages show the work that has been done in perfecting this book. The many forms of motors and other apparatus adapted to the use of these fuels are described in detail, an appendix giving an account of the recently introduced "Bonecourt" method, the joint invention of Professor Bone and Mr. M'Court, and of the two methods which have been devised therefor.

The work is a magnificent treatise upon one of the most important industrial questions, and reflects great credit on its original author, as well as on those who have carried on his work. The mechanical execution deserves high praise, the text, tables, illustration and maps being all excellent. The edition maintains the status which the work acquired when first issued, namely that of leader in its field.

HENRY LEFFMANN.

REVUE D'OPTIQUE, THÉORIQUE ET INSTRUMENTALE, Annee 1, No. 1.

This review of optical science is essentially the successor of the *Revue Générale d'Optique et de Mécanique de Precision*, but it has been deemed advisable to make an entirely new start, and to increase the efficiency of the publication. This change has been made because the journal now goes under the care of a newly formed "Institute of Optics," an organization duly authorized by the Minister of Public Instruction and, in accordance with French law, declared to be of public advantage.

Dr. Charles Fabry, well known in the field to which the journal is devoted and who received the Franklin medal for his researches in spectroscopy, is one of the most active members of the new society, and will take an important part in its publications. As Major Fabry, he came to the United States in the early summer of 1917 to assist our government in those features of war which require modern scientific methods, and his mission was of great use. Fabry's work in connection with Michelson, Perot and Benoit led to the development of a method by which the length of the standard meter-bar was fixed by means of light waves.

The new journal begins under very favorable auspices and will give steadily interesting and valuable contributions in its field. It will appear monthly in octavo form of about 48 pages. The first number contains a paper by Fabry and Buisson on a "Universal Screenless Photometer," another by Chrétien on "Newtonian and Aplanatic Telescopes" and a report on progress by Guadet, the especial subject being the use of the astronomical interferometer. Other articles are: Apparatus presented, a bibliography of current literature and a discussion of the commercial activity of Germany in optical apparatus. Among the "apparatus presented" is to be noted a new stereoscopic camera. French photographers are giving a great deal of attention to this field of photography, which at present attracts but little attention in America, though was once very popular.

HENRY LEFFMANN.

PRÉCIS D'ARITHMÉTIQUE. Par J. Poirée. 8vo., paper, 62 pages. Paris, Gauthier-Villars et Cie. Price 7f, 50.

Elementary arithmetic is a good introduction to the study of mathematics, because it gives the beginner, under form of concrete examples, the methods of reasoning ranging from the simplest to the most complex. Notwithstanding such advantage, the field is much neglected by the generality of pupils, for which they are, perhaps, not wholly to blame, since authors see the more important and difficult phases and do not wish to leave these in the shadow, thereby overlooking the more elementary but simpler phases of the reasoning. M. Poirée has been able to avoid this difficulty and has condensed in a limited number of pages all that belongs to the classic course in this field, and has added a chapter which is an introduction to the theory of numbers.

Eliminating all that is not entirely indispensable, the author passes rapidly, but with care, to principles of enumeration, the fundamental operations, division, primary numbers and puts the theorems in a logical order. The treatment of fractions affords an opportunity to introduce a dissertation on the theory of limits, that beginners find difficult to understand. In connection with the section on square root he discusses the subject of irrational numbers. These different sections are fully illustrated with examples. The work is, therefore, a useful contribution to this field.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 113, Tests on Air Propellers in Yaw, by W. F. Durand and E. P. Lesley. 37 pages, diagrams, quarto. Washington, Government Printing Office, 1921.

This report contains the results of tests to determine the thrust (pull) and torque characteristics of air propellers in movement relative to the air in a line oblique to the line of the shaft, and specifically when such angle of obliquity is large, as in the case of helicopter flight with the propeller serving for both sustentation and traction.

Report No. 116, Applications of Modern Hydrodynamics to Aeronautics, by L. Prandtl. 61 pages, illustrations, diagrams, quarto. Washington, Government Printing Office, 1921. This report gives rather briefly in part one an introduction to hydrodynamics which is designed to give those who have not yet been actively concerned with this science such a grasp of the theoretical and underlying principles that they can follow the subsequent developments. In part two there follows a separate discussion of the different questions to be considered, in which the theory of aerofoils claims the greatest portion of the space. The concluding portion is devoted to the application of the aerofoil theory to screw propellers.

PUBLICATIONS RECEIVED.

Analogies Mécaniques de l'Électricité, par J. B. Pomey. 150 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1921. Price 15 francs.

U. S. Department of Agriculture, Bulletin 1025. Studies in the clarification of unfermented fruit juices, by Joseph S. Caldwell. 30 pages, 8vo. Washington, Government Printing Office, 1922.

U. S. Bureau of Mines: Technical Paper No. 284, Coal and Coke Mixtures as Water-gas Generator Fuel, by W. W. Odell, Illinois coal mining investigations coöperative agreement. 32 pages, plates, 8vo. Washington, Government Printing Office, 1921.

National Advisory Committee for Aeronautics: Technical Notes, No. 78, Impact Tests for Woods, by Bureau of Standards. 17 pages, diagrams, photographs, quarto. No. 80, The Deadweight of the Airship and the Number of Passengers that Can Be Carried, by Colonel Crocco. Extracts from the *Transactions of the Aeronautical Experimental Institute*, Rome, Italy. 20 pages, diagrams, quarto. Technical Notes, No. 81, Langley Field Wind-tunnel Apparatus. Part I, Regulators for Speed of Wind-tunnel Drive Motor. Part II, A Vernier Manometer with Adjustable Sensitivity, by D. L. Bacon. 9 pages, illustrations, quarto. Washington, The Committee, 1922.

The Application of the Principles of Efficiency to the Teaching of Chemistry, by J. Norman Taylor. 10 pages, 8vo. Reprinted from *School Science and Mathematics*, December issue, 1921. Chemical Nomenclature and Pronunciation, by J. Norman Taylor. 2 pages, 8vo. Illustration of Molecular Motion, by J. Norman Taylor. 2 pages, 8vo. Reprinted from June, 1920, issue *School Science and Mathematics*. The Utility of Mineralogy in Elementary Chemistry by J. Norman Taylor. 2 pages, 8vo. Reprinted from May, 1921, number of *School Science and Mathematics*.

New Potash Areas in the United States. (*Press notice, U. S. Geo. Sur.*)—The potash problem became acute during the war and led to energetic search for native sources, with some satisfactory results. In boring for oil recently in Texas, potash deposits have been found at points considerably distant from the localities known hitherto. The data at hand, however, are not sufficient to determine positively the thickness of the beds. The well-drillers, being interested only in the oil, have not been attentive to the preservation of the samples of the strata encountered, but the likelihood of the presence of potash will cause them to be more attentive in future drillings. Some of the samples already submitted have shown high potash content, but more extended examinations, which are now in progress, will give more definite information.

H. L.

CURRENT TOPICS.

Duration of Impact of Bars. E. W. TSCHUDI. (*Phys. Rev.*, Dec., 1921.)—Let two metal bars approach each other and collide. After an instant they will separate. How is this brought about? There are two explanations offered. According to one a compressional wave starts in each bar from the end in contact, travels to the distant end, is there reflected as a wave of tension, comes back to its starting point and pulls its bar away from the other. By this theory the time the bars remain in contact should be in proportion to the length of the shorter bar, because the wave must go to the distant end and return before the bars can separate. Further, the velocities with which the bars are moving at the moment of impact should make no difference as they will not affect the velocity of the wave in the bars. The present experimenter finds not alone that the time of contact is not proportional to the length of the shorter bar but also that velocity before impact does affect the duration of contact. These negative results seem to disprove the theory stated above. Further evidence in the same direction was obtained by the use of model bars of equal length made up of steel springs loaded in order to reduce the speed of wave propagation. The progress of the compressional wave could be followed with the eye. It was seen that this wave had traversed only about one-third of the length of each bar by the time that they rebounded from one another.

The second theory, due to Hertz, relates primarily to the impact of curved surfaces. It assumes that the effect of the collision is localized near the place of contact. "The pressure gradually increases until the bodies are brought to rest and then decreases until they are separated again." Measurements made of the duration of contact of metal spheres verify this theory and encourage the author to adapt it to the case of impinging cylinders.

When a cast-iron sphere, 7.62 cm. in diameter, struck with a speed of 96 cm. per sec. a like sphere at rest, the contact lasted .00033 sec. When the velocity was 14 cm. per sec., contact lasted .00058 sec. When a cylinder of hot-rolled machinery steel, 2.86 cm. in diameter and 15.9 cm. long, moving with a speed of 90 cm. per sec., struck an equal cylinder at rest the contact lasted .0002 sec. Upon reducing the original velocity to one-fifth of its former value, the time of contact increased by about 60 per cent.

When one piece of metal came into contact with the other the charging circuit of a condenser was closed. The charge imparted to it depended on the duration of contact. The condenser was later discharged through a ballistic galvanometer, from whose fling primarily the charge and secondarily the duration of contact was derived.

G. F. S.

Annual Report of the Director of the Department of Terrestrial Magnetism for 1920. Carnegie Institution.—Under the direction of Dr. L. A. Bauer the magnetic survey of the earth proceeds. On the sea the *Carnegie* has, no doubt, long since completed her latest cruise of 62,000 miles after winding her sinuous way across the Atlantic, the Pacific and the Indian Oceans. If the voyages of her scientific predecessor, the *Galilee*, are included, the total distance covered is greater than the distance from the earth to the moon by some three circumferences of the earth. The change of the vessel's engine so that it operates on gasoline instead of on producer gas has proved satisfactory. It has been possible to furnish results of the ocean survey to chart makers within two or three months of the date of the observation. In addition to the magnetic work on board the *Carnegie* observations on atmospheric refraction, on the occurrence of thunder at sea, on St. Elmo's fire, and on ocean currents as well as on the following features of atmospheric electricity, potential-gradient, ionic content, conductivity, penetrating radiation and radioactive content of the atmosphere were made.

On land Mr. Frederick Brown successfully conducted expeditions for magnetic survey through Cameroon to Lake Tchad and from the west coast of Africa to Portuguese East Africa and Madagascar. At certain places he connected with former surveys, thus rendering possible the determination of secular changes in the earth's magnetism. In the winters of 1918–1920 Captain Amundsen secured a series of magnetic measurements at forty places on the coast of Siberia. In all, from 1905 to 1920, observations have been made at about 4000 stations on land, in 121 countries and on the islands of the sea. To do this observers have traveled a million miles.

It must not be inferred that all the work of the Department is done in the field. A great part is carried on in the Laboratory of Terrestrial Magnetism in Washington. Here are focused the results of the survey and here they are interpreted and applied to the solution of problems.

Every year furnishes additional reason for rejoicing that so great a scientific institution exists among us.

G. F. S.

Positive Ray Analysis of Lithium and Magnesium. A. J. DEMPSTER. (*Phys. Rev.*, Dec., 1921.)—Atoms with a positive charge acquire a velocity by falling through a difference of potential. A magnetic field bends into a semicircle a narrow beam of such moving atoms. The mass of the atom can be computed from the fall of potential, the radius of the circle, the strength of the applied magnetic field and the elementary electric charge. Two isotopes of lithium were identified with atomic weights of 6 and 7, their relative proportions changed from time to time. Magnesium gave three isotopes with atomic weights of 24, 25 and 26.

G. F. S.

On Majorana's Theory of Gravitation. H. N. RUSSELL. (*Astrophys. J.*, Dec., 1921.)—From the result of certain pendulum experiments Majorana was led to conclude that a mass of lead exerted less gravitational force when surrounded by a jacket of mercury than when not so surrounded. To account for this he proposed a law of gravitation which is the same as Newton's law when no matter exists along the line joining the two attracting particles, but which, in the case that matter does there exist, has an added factor of exponential form that causes a reduction of the calculated force between the two particles. The Princeton astronomer examines the consequences of this law when applied to the solar system. If the presence of matter between two bodies does diminish their gravitational attraction, then the attraction of the central parts of a sphere is reduced by the presence of the surface portions and the mass of the sphere as calculated from its attraction on other bodies will be actually less than its real mass. In the case of the sun its apparent mass would be only .33 of its real mass, the correctness of Majorana's constant of gravitational absorption being assumed. For the earth the corresponding fraction is .981, for the moon .997. We cannot disembowel the moon or a planet to find which law, Newton's or Majorana's, gives the correct value of the mass, but an application of Kepler's Third Law, shows that the proposed law carries implicitly with it other distances of the planets from those accepted on the basis of Newton's law. The mean distance of Jupiter from the sun would be 1.04 per cent. less than the generally accepted value, and the planet's longitude would not agree with its predicted value. In the instance of the moon the new law would require the application of a different accelerating force. "Its introduction would play utter havoc with the whole lunar theory." "We are forced therefore to the conclusion that upon the hypothesis that there exists an absorption of gravitational force in matter, without change in its inertial mass, the coefficient of absorption cannot exceed one ten-thousandth of that derived by Majorana from his experiments, and must be hopelessly beyond the reach of investigation in the laboratory."

G. F. S.

The Nitrogen Problem.—The possibility of recovering a greater proportion of the nitrogen from coal is the subject of a paper by GIANOLI in the *Giornale di Chimica*, who, among other matters, reviews the technical difficulties relating to coal distillation in the presence of alkali-metal chlorides. Gianoli says that to carry out such a method, extensive alterations would be needed in the gas plants, the cost of which would be likely to exceed the profits of the procedure. The liability to the production of corrosive volatile chlorides must also be considered. The coke would contain much mineral matter. The process seems best suitable for a low-grade gas plant. Incidentally, the question of utilizing the nitrogen oxides produced in internal combustion engines is examined.—*Chem. News.*

H. L.

Research Graduate Assistants in the University of Illinois.—The Director of the Engineering Experiment Station of the above University invites applications for positions under the auspices of the station. The University maintains fourteen Research Graduate Assistantships in the Engineering Experiment Station. Two other such assistantships have been established under the patronage of the Illinois Gas Association. These assistantships, for each of which there is an annual stipend of $600 and freedom from all fees except the matriculation and diploma fees, are open to graduates of approved American and foreign universities and technical schools who are prepared to undertake graduate study in engineering, physics, or applied chemistry. H. L.

Detection of China Clay by Means of the Microscope.—China clay is used to adulterate fine meals. The British "Government Chemist" has devised the following procedures for the detection of the presence of this adulterant (*Analyst*, 1921, xlvi, 496). The fine dust, which passes through a sieve with 100 meshes to the inch, is ignited and the residue is examined microscopically by means of polarized light and crossed Nichol prisms. Or the sample is shaken with ether to obtain an ethereal suspension of the kaolin and the starch. The ethereal layer is decanted; the ether is evaporated; the residue is ignited; and the ash is examined microscopically. If it consists chiefly of fine crystals of feldspathic origin, kaolin was present. J. S. H.

Precipitation of the Sulphide from Solutions of Pentavalent Arsenic.—J. H. REEDY, of the University of Illinois (*Jour. Am. Chem. Soc.*, 1921, xliii, 2419), states that the presence of a soluble iodide, such as ammonium iodide, greatly accelerates the precipitation of arsenic as its sulphide, when hydrogen sulphide is passed into the aqueous solution of an arsenate acidified with hydrochloric acid. The iodide reacts with the arsenic acid to form arsenious acid and iodine. The hydrogen sulphide reacts with this iodine to produce hydriodic acid; and the entire cycle is repeated. The hydrogen sulphide also precipitates arsenious sulphide from the resulting solution of arsenious acid. J. S. H.

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